VISIT…

PART III
TRENDS

Copyright © 1999 Marcel Dekker, Inc.

28
Automotive Trends in Europe

R. David Whitby
Pathmaster Marketing, Ltd.
Woking, England

I. INTRODUCTION

Emissions legislation, fuel economy, and vehicle performance continue to be the major driving forces behind the design and choice of engines and transmissions in Europe. The legislation and market forces that affect vehicle manufacturers have a major effect on oil and additive companies. As a result, fuel and lubricants suppliers continue to strive to meet the requirements of existing and advanced technologies emerging from the motor and transport industries. These forces appear to be set to dominate Europe for me foreseeable future, especially if the messages emanating from the 1997 World Environmental Conference in Kyoto are to be enforced.

In the foreseeable future, European automotive fuel composition and performance will be affected mainly by legislation derived from the European Auto-Oil process, which has become increasingly dominant in recent years. As well as affecting fuel specifications and performance, the process affects vehicles, in the form of emission limits, and therefore influences vehicle/engine design and technology, which in turn affect lubricant quality.

In Europe, engine lubricant performance standards are largely initiated by the Association des Constructeurs Européens d'Automobiles European (ACEA), via specified sequences of tests covering different categories for both gasoline and diesel engines. The standards are discussed in a consultative process with the European petroleum additive industry association (ATC) and the European oil marketing industry association (ATIEL), but the performance requirements essentially reflect the external driving forces that influence the original equipment manufacturers (OEMs) in their choices of vehicle technology. The Coordinating European Council (CEC) establishes jointly agreed performance tests for the evaluation of fuels and lubricants on behalf of the motor, oil, petroleum additive, and related industries.

II. THE EUROPEAN AUTO-OIL PROGRAMME

As a result of rising public concerns about motor vehicle exhaust emissions and their effects on health and air quality, the European Parliament and Council instigated, in 1994, the European

Copyright © 1999 Marcel Dekker, Inc.

Union (EU) Auto-Oil Programme as a joint activity between the EU Commission, the European oil industry (EUROPIA), and the European motor industry (ACEA). Auto-Oil was designed to provide European legislators with a rational scientific basis for the setting of future European vehicle exhaust emission limits for road transport on a cost-effective basis, linked to air quality needs, taking into account motor technology and fuels as well as other nontechnical measures, such as inspection, maintenance, and traffic management systems.

Guidelines and principles for this unique approach to cost-effectiveness measures were agreed by the European Parliament and Council in Article 4 of Directive 94/12/EC. Although this directive applies to the emissions of light-duty vehicles for 1996–97, guidelines were included for the creation of legislation for implementation in 2000, and beyond. Article 4 of the directive indicated that the Commission should adopt measures that "produce effects to meet the requirements of the Community's air quality criteria" and "the measures shall be proportional and reasonable in the light of the intended objectives." Also, a cost-effectiveness assessment would be taken of the potential contributions from traffic management (e.g., by spreading the environmental costs appropriately), enhanced public transport, new propulsion technologies (such as electric vehicles), and the use of alternative fuels (such as biofuels).

Since 1970, when the first exhaust emission legislation for motor vehicles emerged, progressively more severe legislation has been introduced in Europe, by general agreement between national governments and the motor industry. European emissions legislation in the 1990s includes directives on large combustion plants, hydrocarbon vapor recovery (1990), vehicle emissions (1993), and sulfur in gasoil (1993), in addition to the framework 1994 directive. The Auto-Oil Programme sought to extend the participation and consensus to cover all EU countries and to establish both a technical base and a mechanism for evaluating cost-effectiveness.

Auto-Oil is a large undertaking, bringing together many groups for the first time at a European level in a cooperative program. The EPEFE research program into the inter industry relationships between vehicle and fuel technologies and their impact on exhaust emissions, which is just one part of the Auto-Oil process, has cost more than $11 million, not including the cost of developing prototype technology and advanced fuels. EPEFE is an advisory group of 14 motor companies (ACEA) and 32 oil companies (EUROPIA). The research program involved 16 gasoline and 19 diesel-engined light vehicles, 5 heavy-duty engines (all 1996 or later specification), 12 gasolines and 11 diesel fuels, 17 vehicle/engine and 4 fuel laboratories, and more than 2000 emission tests, and generated over half a million data points.

The EPEFE program was designed to add to data already available in Europe (and from the United States, where relevant), to help establish the relationships between fuel composition and vehicle technology and to identify and quantify the reductions in road traffic emissions that might be achieved by combining advanced fuels with advanced vehicle and engine technologies under development for the year 2000. Results from the EPEFE program were tabulated and employed to develop complex equations that were associated with fuels and vehicle and engine technologies for inclusion into the commission's air quality modeling studies. This process facilitated the search for the optimum combination of measures to achieve the EU's air quality objectives. The program involved:

Emissions 2000 workshop (1992)
Assessment of existing data (1993)
EPEFE research program (1993–1996)
Air quality modeling
Air quality targets

Copyright © 1999 Marcel Dekker, Inc.

Cost-effectiveness studies
Vehicle and fuel options and their input into the main Auto-Oil assessments

The air quality target bands are listed in Table 1.

A draft report was released in July 1995, at a meeting organized by the Commission to brief member states on the status of the Auto-Oil Programme. It was found that previously implemented measures, including the mandatory use of catalytic converters from the beginning of 1993, the introduction of a 0.05 %m/m limit for sulfur in diesel fuel and the halving of exhaust emission limits in 1996, would have a significant effect in reducing vehicle-derived air pollution between 1997 and 2005, despite the expected growth in road traffic. From 1990 to 2010, the research showed that hydrocarbon (HC) is expected to decrease to less than 30% of the 1990 level, nitrogen oxides (NO_x) is expected to decrease to around 40%, and carbon monoxide (CO) is expected to decrease to around 45%. Additionally, already agreed measures will result in a reduction in ground ozone of from 20 to 30% by 2010. With a total ban on city traffic, ground ozone will be reduced by a further 10%, showing the importance of controlling stationary sources as well as vehicles.

However, it was also found that the impact of the already agreed measures varies from country to country depending on existing vehicle population and consumer buying habits. Low rates of purchasing new vehicles in some European countries are likely to delay the beneficial impact of the agreed measures. (On average basis, the life span of a European passenger car is between 10 and 15 years, while that for commercial vehicles is somewhat longer.)

The Commission had a mandate from Directive 94/12/EC to establish compliance of reactive and nonreactive pollutants in the urban environment by addressing the question of whether "summer smog" was responsible for respiratory and other health-related problems due to ozone levels pushed too high by traffic pollution. Air quality target bands were identified, based largely on the World Health Organisation (WHO) guidelines, with upper and lower (tighter) target bands. A seven-city air quality study was undertaken to assess current and future air problems associated with reactive and nonreactive pollutants. The seven cities (London, the Hague, Cologne, Lyon, Milan, Madrid, and Athens) were chosen as representative of urban Europe.

The main conclusions from the emissions and air quality modeling studies confirmed the following statements:

Urban air quality in all seven cities has improved significantly as a consequence of already agreed measures
CO and benzene will meet the lower criteria by 2000/2005.

Table 1 European Air Quality Target Bands

Pollutant	Time Measure	Target ($\mu g/m^3$) Upper	Lower	U.S. standard	Rationale
NO_2	1 h avg	200	93	100[a]	EU NO_2 directive
CO	8 h avg	10	5	10	WHO
Benzene	Annual mean	16	10 (2.5)[b]	None	Compromise based on MS actions
Ozone	8 h avg	120	120	156	WHO
	1 h avg	180	180	235	EU ozone directive

[a]Annual mean: EU annual mean target is 50 $\mu g/m^3$.
[b]Longer term target value.
Source: European Commission.

Copyright © 1999 Marcel Dekker, Inc.

Further emission reduction measures are needed for $N0_2$, in accordance with the lower criterion band for this gas

Severe NO_x emission reductions are required to achieve NO_2 targets in almost all the seven representative cities.

The outcome showed clearly that NO_x is the real problem for complete compliance with the lower air quality band. As an example, NO_x reductions for the year 2010 are 55% for Athens and 40% for London. CO and benzene were not found to be a problem after 2000 and 2005, owing to the benefits of the existing and agreed measures. Table 2 shows the required reductions for each pollutant in each city for 2005. The Commission also recognized that reductions in NO_x bring other benefits. For example, every 10% reduction in NO_x would generate reductions of 12–15% in CO, 9–13% in HC, 12–15% in benzene, and 10–11% in particulates.

While the existing and agreed measures, together with those measures required to meet the NO_x air quality targets, will significantly reduce ozone levels, they will not be sufficient to meet the ozone air quality target. Even the extreme measures directed at traffic will have limited effect. This clearly demonstrates the need for a totally integrated approach aimed at reducing emissions from all sources, including stationary sources.

The fuel parameters and ranges studied during the program are shown in Table 3, and the vehicle and engine technologies assessed are shown in Table 4. Preliminary results released at the beginning of 1996 indicate that about 90% of European cities can meet the NO_x targets with a set of nonextreme measures. The remaining 10% of European cities, which generally lie in southern Europe, cannot meet the NO_x targets, even with a much more severe set of measures. Only the use of local, nontechnical measures such as fleet replacement, traffic management, enhanced public transport, and better vehicle maintenance, offers any hope of attaining the NO_x emission reduction targets in these cities.

City diesel, often considered to be an important potential solution, is believed by the oil industry to be not cost-effective. However, it is recognized that there may be scope for urban buses, municipal trucks, and taxi fleets using compressed natural gas (CNG) or liquid propane gas (LPG) as a dedicated fuel. Nontechnical measures are also to be included in the analysis, as

Table 2 Summary of Required Emission Reductions in 2005, from Euro-Oil Urban Air Quality Modeling

	Pollutant and concentration ($\mu g/m^3$)								
	NO_x			CO			Benzene		
		Reduction			% Reduction			% Reduction	
City	1990 Level	Upper 186	Lower 66	1990 Level[a]	Upper 3000	Lower 1500	1990 Level	Upper 16	Lower 10
Athens	147	0	55	992	0	0	7.0	0	0
Cologne	103	0	35	454	0	0	3.0	0	0
The Hague	69	0	5	361	0	0	2.0	0	0
London	111	0	40	589	0	0	2.7	0	0
Lyon	115	0	45	653	0	0	4.6	0	0
Madrid	147	0	55	NA	0	0	5.6	0	0
Milan	152	0	55	NA	0	0	5.2	0	0

[a] not available.

Source: European Commission.

Copyright © 1999 Marcel Dekker, Inc.

Table 3 Fuel Parameters and Ranges Studied in Auto-Oil

	Study range	
Parameter	Gasoline	Diesel
Density, kg/m^3	—	820–855
Sulfur, ppm	30–500	50–500
Lead, g/L	0.005–0.013	—
Olefins, %	5–15	—
Oxygenates, %	0.0–2.7	—
O_2		
Aromatics, %	20–50	—
Polyaromatics, %	—	1–8
Benzene, %	0.7–3.0	—
RVP, Pa	60–80	—
E 100, %	35–65	—
E 150, %	85–90	—
Cetane number	—	50–58
T 95, °C	—	330–370

Source: European Commission.

are inspection and maintenance programs, including on-board diagnostics and remote emission detection. However, non technical measures affect emission levels only indirectly, by changing driver and vehicle owner behavior as a result of economic incentives or penalties.

The EU Auto-Oil process has five steps: assessment of existing data, collection of additional data, air quality modeling and target setting, performance of cost-effectiveness studies, and

Table 4 Vehicle and Engine Technologies Studied in Auto-Oil

Gasoline	Diesel
Improved electronic engine control	Very high pressure injection
Exhaust gas recirculation (EGR)	Increased cylinder pressure
Improved and low 'light off' washcoats	Improved clearance volumes
Greater catalyst loading	Multivalve engines
Dual oxygen sensors	Exhaust gas recirculation
Sequential fuel injection	Controlled intercooling
Reduced engine clearance volumes	Variable pressure turbo
Leak-free exhausts	Electronic unit injectors
Cylinder disablement	Particulate traps
Electrically heated catalysts	De-NO_x catalysts
Low-temperature stable lambda sensors	Manufacturer other
Auxiliary air injection	
Air-assisted injectors	
Double-walled exhaust pipes	
Close-coupled & underbody coats	
Carbon canisters—improved charcoal	
Low loss systems/minimum joints	
Manufacturer other	

Source: European Commission.

Copyright © 1999 Marcel Dekker, Inc.

drafting of proposals for standards and actions. The first program, now called Auto-Oil I, reached the last stage in late 1996, having identified urban NO_x is a key driver. Additional steps were then considered, which included such particulate mass and ozone precursors as volatile organic carbons and total NO_x. The inclusion of these substances will reduce emissions further, but will also increase the costs of the cost-effectiveness measures. Particulates (PM) remain the main unknown in terms of derivation, size and life span, and impact on air quality and health, and in terms of their contribution to air pollution. Currently, no WHO standards exist for particulates. Debates and studies on this topic have grown, reflecting a growing interest in using gaseous fuels, with potentially very low particulates, to replace the use of diesel in buses, trucks, and taxis.

Auto-Oil I aimed to produce cost-effective options for reducing emissions based on rational scientific principles; all possible technical and nontechnical approaches were considered. Most of the practical studies have been completed, and the political debate started toward the end of 1997. The current proposals for emissions limits consistent with optimum cost-effectiveness are described in Section IV.B.2. A draft directive is expected to emerge from the Commission later in 1998 for consideration by the EU member states and ultimately by the European Parliament.

III. CURRENT STATUS OF AUTOMOTIVE FLUIDS IN EUROPE

A. Engine Oils

1. Gasoline Engine Oils

The development of engines that combine good fuel economy and low emissions with high performance requires, as always, the development of improved engine lubricants. As a result, ACEA introduced new crankcase lubricant test sequences in March 1998. For the first time, engine manufacturers mandated specific types of lubricant that provide a minimum fuel economy benefit. The new ACEA ’98 sequences are very similar to the ’96 sequences, except for the addition of fuel economy requirements in the Al and B1 sequences and the addition of new B4 and E4 categories. ACEA prefers fuel economy claims to be based on the M111 fuel economy test. Volkswagen is the main driver behind the introduction of the B4-98 sequence, the need for which is questioned by other engine manufacturers.

The original ACEA ’96 sequences were introduced in January 1996, to replace the earlier specifications of the Comité des Constructeurs du Marché Commun (CCMC). CCMC, founded in 1972 as an association of European manufacturers, was replaced by ACEA, which includes U.S.-owned companies that manufacture vehicles in Europe, in 1991.

ACEA, in the 1998 sequences, has also included (again for the first time) a view of future requirements intended to clarify the performance parameters the association wants to address. Further work by the industry groups is intended to add to this list. A particular point of note is the inclusion of the yet-to-be-defined E5 diesel engine oil category.

Until March 1,1999, lubricant companies will be permitted to introduce products that claim performance to the ACEA ’96 levels. From then on, new products must meet the ACEA ’98 performance levels. The association intends to ensure that oils in the market after March 2000 will meet the latest standard as a minimum. The ACEA ’96 standards will then be withdrawn, effectively making this performance obsolete.

At the start of the sequences document, ACEA clearly states that it has no wish to see oil companies making extravagant claims based on the sequences. It wants product labeling to focus on customers’ needs, using unambiguous and readily recognized performance labels, which are easy to read and not cluttered with the administrative issue number, which is intended for use by the industry not by the consumer, or the year of issue (’96 or ’98). The association believes

Copyright © 1999 Marcel Dekker, Inc.

that the lubricants industry has a collective obligation to minimize uncertainty, inconsistency, or obscurity, although consumers do not need to be aware of behind-the-scenes issues.

In addition to the ACEA sequences, which are already very comprehensive, some European vehicle manufacturers have their own lubricant specifications. The list of such OEM specifications continues to grow, and the conventional reasons given are that OEMs are seeking extra performance and that lubricant suppliers want additional product features to strengthen their marketing claims. For passenger car motor oils (PCMOs), it is clear that lubricant marketers still regard approvals from Mercedes-Benz and Volkswagen as the basis of performance claims for their mainline oils. Other OEMs are differentiated by their own product claims. The current lubricant requirements of VW, Mercedes-Benz, BMW, and Porsche are summarized in Table 5.

OEMs are keen to develop higher lubrication specifications to support advanced engine designs. The impact of this, however, is to reduce product life cycles dramatically. In the past, a relatively simple lubricant formulation might have a working life of up to 10 years. Now, a much more complicated product may only be in use for 2 or 3 years before a higher specification renders it obsolete.

Since testing and evaluation of new lubricants can cost up to $600,000, payable by lubricant and additives suppliers before product sales materialize, there is understandable concern mat it may be difficult for companies to recover their development costs if the specifications are driven higher too quickly. European lubricant manufacturers are keen to avoid the U.S. experience, where the ILSAC (International Lubrication Specification and Approval Committee) sequences, set by U.S. and Japanese motor manufacturers, went through a number of changes in very short succession, causing additives manufacturers to spend more and more money in an effort to keep up with the changing specifications.

The ACEA ‘98 requirements appear to be not too dissimilar to the original sequences, and the modifications to engine oils should be achievable by me additives and lubricants industry. The ACEA structure is also leading to more transparency and standardization of test results through the industry. Previously, replicability of results had caused problems, but the ACEA arrangements introduced standard test procedures, and all the results must be registered. The tests are done in the same way and the data are presented in the same way. This industry-wide bank of information also helps the European Coordinating Council (CEC) to improve the test procedures.

2. Diesel Engine Oils

The new ACEA E4 sequence includes the new OM441LA engine test for bore polish and piston cleanliness, with intercooler compressor turbocharger deposits as rate and report. These turbocharger deposits are still the subject of considerable discussion. Alternative test methods, involving pressure changes rather than weight of deposits, are being considered for inclusion in a new E5 sequence. It is unlikely that the MTU glassware test will be used. The longer Mack T-8E (“extended”) test is designed to control oil viscosity increase caused by soot formation.

Key heavy-duty diesel tests for E class oils are based on Mercedes engines at the following performance levels:

El: OM364A or OM364LA at equivalent performance to MB p227 level
E2:OM364A or OM364LA at equivalent performance to MB p228.1 level
E3:OM364A or OM364LA at equivalent performance to MB p228.3 level; Mack T-8 is API CG-4 level
E4:OM44ILA at MB p228.5 level

Operators of heavy-duty trucks generally know what they want when it comes to cost of ownership and equipment durability. The addition of Scania’s Long Drain Field Test Specification,

Copyright © 1999 Marcel Dekker, Inc.

Table 5 Passenger Car Motor Oil Requirements of Individual European OEMs

OEM	Specification or classification	Requirements and comments
VW	500.00/501.01/505.00	Approvals expired after January 3, 1997. Renewable, if test results are less than 5 years old.
	502.00	Mandatory level for all new gasoline oil approvals. Deletes VW1302 PV9800 and VW P 1431 (ICTD) from VW 500.00. Adds VW PV1449 (T4).
	New specifications	Gasoline spec will have HTHS viscosity of 2.9–3.0 cP. Diesel spec will be more severe than ACEA B4.
Mercedes-Benz	p229.X	Release date in 2H98, with approvals from 1H99. Oil drain interval extension with electronic acid, ASSYST. ACEA A3/B3/B4-98 performance level. MIII sludge, high severity, but fuel economy limits not yet decided. OM602A at p228.5 levels. Likely to match VW severity in T4 and TDI tests. HTHS viscosity of less than 3.5 cP is possible.
BMW	Long-life oils	5W or 10W gasoline engine oils targeted at drain interval of 25,000–30,000 km. ACEA A3/B3 minimum performance. Plus 225-hour in-house endurance test in M44 engine. Evaluate wear, piston cleanliness, oil consumption, and used oil properites, relative to a reference oil.
Porsche	All-season engine oil	Minimum quality API SH, ILSAC GF-I, or ACEA A3 for 15w-40 oils. Porsche air Entrainment Test required for 5W-40 and 10-W-40 oils. 120-hour Porsche Engine Test required for 0W-40 and xW-30 oils. HTHS viscosity 3.5 cP (min) NOACK volatility 12% (max) List closed on April 30, 1998.
	New classification	New list to be issued early in 2000 for xW-40 and xW-30 oils. No extra testing for oils with KV100 above 11.0 cSt. Porsche Engine Test required for oils with KV100 below 11.0 cSt. New test to be developed for ACEA A1 oils.

Source: Paramins (Exxon Chemicals).

with its requirement of rigid field trials for any aspiring lubricant, adds to the performance credentials already established by Volvo with the VDS and VDS-2 specifications. ACEA has challenged its industry partners to develop a new specification, to be known as E5-99, by the end of 1998.

As with some gasoline engine manufacturers, MAN, Scania, Volvo, and Mercedes-Benz have their own requirements in addition to the ACEA sequences. Those specified by MAN are shown in Table 6.

Copyright © 1999 Marcel Dekker, Inc.

Table 6 Heavy-Duty Diesel Engine Oil Requirements of Individual European OEMs

OEM	Specification or classification	Requirements and comments
MAN	270/271	ACEA E2, MB p228.1 minimum performance. Non–all-mineral formulations restricted to 10W-30 (100% unconventional) and 10W-40 (for minimum 25% unconventional).
	3275 (recoded QC 13-017)	ACEA E3 minimum performance. 5W oils must be 100% unconventional. 10W oils must be minimum 25% unconventional.
	3277	ACEA E4 minimum performance. OM441LA and OM602A at MB p288.5 severity. Plus MAN/MTU turbocharger deposit test.

Source: Paramins (Exxon Chemicals).

3. Engine Oil Drivers and Trends

Current engine oils are required to function effectively for much longer and under more severe operating conditions than ever before. Engines have become more complex, with a larger number of working parts engineered to finer tolerances and a greater mix of different materials. The aerodynamic styling of many car designs, with very few cars having appreciable radiator grilles for example, has reduced sharply the amount air cooling around the engine. Front wheel drive and the increased use of powered equipment, such as power steering, servo-assisted braking and air conditioning, all driven from the engine, have also reduced free space under the hood to a minimum. As a result, engines typically run at higher temperatures.

Lubricants also must keep engines clean and efficient for longer because extended maintenance intervals require engines to run much longer. As an environmental improvement, engine oils are required to volatilize (evaporate) less at higher temperatures, thereby diminishing their contribution to the quantity of part-burned hydrocarbons (from the fuel) emitted to the atmosphere through the exhaust system.

The pressures driving the overall performance demands on engine lubricants will continue to grow in the foreseeable future. Some of these pressures for passenger car engines include smaller or flatter oil sumps, improved oil ring efficiency, and lower oil consumption levels, and use of on-board oil sensors to give extended oil drain intervals. Pressures for commercial and off-highway diesel engines include use of on-board oil sensors and computers, again to allow extended oil drain intervals.

Many of the future performance requirements of heavy-duty diesel oils are not new in principle. One of the major objectives of the changes is to provide optimum fuel economy and customer satisfaction. However, changes in engine design and engine–fuel injection management strategies are leading to increased soot-related oil thickening and wear. As a result, improved soot-handling capacity for diesel engine oils is becoming even more important. Increased oil stresses, due to higher specific output, higher temperatures, and longer maintenance intervals, demand more robust detergent/dispersant inhibitor packages with increased resistance to oxidation and nitration. Formulations also need to be optimized with a view to minimizing turbocharger and intercooler deposits, especially in high output engines with closed crankcase ventilation systems.

Copyright © 1999 Marcel Dekker, Inc.

The changes in the last 15–20 years have been dramatic. Around 19,200 km (12,000 miles) is now a commonplace service interval for family cars and over 80,000 km (50,000 miles for trucks), compared with as little as 6400 km (4000 miles) for cars and 30,000 km (18,800 miles) for trucks in the early 1980s. Also, then, new oil was continually being added to top-up the lubricant and replenish its efficacy. Nowadays, many car engines do not need to be topped up with oil between services. Lubricant stress has therefore become a much more serious issue. New base oils, many of them synthetic or severely hydrocracked mineral oils, and additives have been developed to counter this problem and to ensure that lubricants can continue to function effectively under much more demanding operating conditions.

During the last few years, the internal combustion engine has been singled out for a great deal of attention and regulation on environmental performance. While emissions from gasoline engines have been reduced by around 85% of the levels of 20 years ago, the trend is likely to continue, and more attention is now being paid to reducing emissions from diesel engines. There has been a general move by all the organizations concerned with automotive development to improve environmental performance. In the case of engine oils, this has been either accompanied or created by increased efficiency and economic performance. For example, the generation of waste oil has been reduced by the use of smaller sump sizes and extended drain intervals. The amount of lubricant consumed during use has been reduced by improved sealing, which eliminates leakage, and tighter engineering design and tolerances, which reduce the amount of oil being burned in the combustion chamber. Increased fuel efficiency is another area of improved environmental performance, achieved through the use of lower viscosity lubricants.

4. Two-Stroke Engine Oils

Two-stroke (2T) engines are enjoying continued global growth in nonautomotive sectors, including agriculture (chain saws and portable power generators) and recreation (jet skis, power boats, and off-road motorcycles). The efficiency of two-stroke engines is being enhanced through new lubricant, fuel, and injection technologies, as well as improved catalyzers, but some environmental concerns remain about the biodegradability and toxicity of residual oils.

Some European OEMs support the use of API TC specification oils for 2T engines, with JASO FB oils as a minimum quality standard and ISO-L-EGD (JASO FD) as the highest quality standard. Other OEMs believe that a higher performance level is needed, with improved lubricity and detergency to meet the ISO-L-EGE specification. The CEC is developing the Piaggio Hexagon test as part of the effort to improve quality levels towards full-synthetic 2T oils.

Water-cooled 2T engines, used for example in boats and jet skis on lakes and seas, are increasingly required to meet biodegradability and toxicity criteria. The U.S. National Marine Manufacturers Association (NMMA) supports only TC-W3-recertified oils, although TC-W and TC-WII products are still being marketed. The newly created International Council of Marine Industries Associations (ICOMIA) specification includes a Sturm-type biodegradability test, replacing the CEC-L-33 test.

B. Transmission and Gear Oils

Automotive industry analysts estimate that by 2005, automatic transmissions will be fitted to 35% of all cars produced in Europe. The 1997 figure was around 15%, whereas by 2015 it is projected that the European share of new automatic transmissions will exceed that of manual transmissions. The main developments have been with continuously variable transmissions (CVTs), which have a beneficial impact on both engine emissions and fuel consumption because of the relatively constant speed of engine operation, and smoother transient accelerations and decelerations.

Copyright © 1999 Marcel Dekker, Inc.

Although many passenger car OEMs offer CVTs in their current models, they are also developing the latest generation of continuously slipping torque converter clutches (CSTCCs). The search for fuel economy and energy efficiency drives the need for special, sometimes OEM-specific, transmission fluids.

New transmission technologies usually place greater physical and chemical stress on fluids, through smaller and hotter boxes and even longer service intervals. Lower viscosity fluids with improved thermal and oxidative stabilities are likely to result. CSTCC fluids need enhanced friction durability, while the latest generation of CVTs, which use steel belts on steel pulleys, present friction control challenges that current automatic transmission fluids (ATFs) do not meet.

As a result, premium quality passenger car ATFs in Europe are likely to focus on Dexron III, Mercon, and specific European OEM approvals for extended drain, using part-unconventional base oils. Second-tier oils will meet Dexron III and/or Mercon specifications, but using conventional base oils, while niche markets will continue to develop for high performance synthetic and part-synthetic ATFs. For trucks and buses, ATFs are likely to move from Dexron IID, Mercon, and European OEM approvals toward Dexron III and higher specification European approvals.

Also in Europe, smaller and hotter manual gearboxes and the need for sustained performance are imposing on gear oils demands that are higher than those in the GL4 and GL5 specifications. This means that OEMs are likely to continue to add their own special performance requirements to these specifications. Segmenting the market into specialized gear oils, fill-for-life manual transmissions, longer drain intervals, and improved synchronizer performance will keep fluid formulators busy for several years. Oils will have to meet ever higher quality demands, and the use of service-fill oils will decline as fill-for-life oils become standard.

Another important objective for manual transmission lubricants is "fill-for-life" performance. In addition to well-known and cost-effective synchromesh friction materials, brass, and molybdenum-coated steel, alternatives recently gaining ground include sintered materials (such as bronze), paper, and pyrolytic carbon. In terms of cars and transmissions, "fill for life" means a working life of around 240,000 km (150,000 miles).

Lubrizol believes that at least 10, and perhaps more, ATF formulations will be needed by 2001 to meet the factory-fill requirements of U.S., European, and Asian vehicle manufacturers. This view is a dramatic change from a few years ago, when many industry observers expected the ATF market to converge. Ford and Fiat are already marketing CVTs in Europe, while Honda, Suzuki, and Nissan market CVTs in Japan. These CVTs have generally been used with engines smaller than 2 L, but the technology is being developed to allow CVTs to be used with larger engines.

One of the leaders in developing new transmissions is ZF Friedrichshafen AG, which has developed the Ecotronic CVT. The company is planning to have this new transmission in smaller European and North American cars by 2002. ZF is developing a CVT for the upper range in the torque capacity of 300 Nm and hopes to begin production by 2003.

Currently, however, the Ecotronic CVT operates with a Dexron D2 ATF that was designed for older ZF transmissions. The company's goal is to develop a new fill-for-life ATF by January 1999. ZF's development of ATF has been held back by the interaction of friction coefficients between steel and steel (variator/belt) or paper and steel (clutch disks), respectively. According to the company, improving one aspect of performance causes problems with the other. Another target is to improve the thermal capacity of the clutch facings.

ZF has indicated that its Ecotronic CVT will be ready for production in 1998. Its initial application will be for 1–3 L displacement engines. The company believes that the Ecotronic transmission has higher levels of comfort and lower fuel consumption than other CVTs. On a comparative basis, the Ecotronic is claimed to reduce fuel consumption by at least 10%.

Copyright © 1999 Marcel Dekker, Inc.

A key factor in achieving lower fuel consumption is using a lower viscosity ATF. But reduced viscosity brings disadvantages, such as higher leakage and reduced gear life. While the reduced gear life can be partially offset by using extreme pressure additives in the ATF, the leakage problem seems trickier to solve. ZF now is looking closely at the optimum additive package for the lubricant, which will require a careful balancing of friction, wear and viscosity agents. The company is also pursuing a "lifetime oil" approach for its transmissions. Initially this product used a fully synthetic ATF, but cost concerns led ZF engineers to develop specifications for a part-synthetic fluid. ZF admits that production of the "lifetime oil" will need careful monitoring for consistency and quality.

The Ecotronic uses a hydrodynamic torque converter in place of the wet multi disk or magnetic particle clutches normally found in CVTs. It uses a steel thrust belt that runs between two lightweight pulleys under electronic control. The distance between the pulleys is changed by a hydraulic system, with the steel belt clamping pressure set to avoid slipping. The hydraulic pump is the radial piston type, requiring a minimum of power input, and the transmission housing is very compact and cost-effective.

This emphasis on saving weight and space means that the overall system will be smaller than conventional transmissions, and the tolerances for the equipment will be very narrow, creating more heat and stress for a reduced volume of lubricant. The objectives were to reduce drag and torque, to reduce leakage caused by reduced oil viscosity, and to reduce the price. ZF engineers have found that a fully synthetic ATF is not needed to get the required performance, since the same results can be achieved using a synthetic blend and additives.

C. Other Automotive Oils

Comparatively small volumes of hydraulic fluids, brake fluids, shock absorber oils (both of which are specialized types of hydraulic fluid), refrigeration compressor oils (for use in either air-conditioning systems or on refrigerated trucks), and greases are used in vehicles. Nowadays, most of these systems are designed to be "filled-for-life," except for brake fluids, which are required by most OEMs to be replaced at least every 2 years.

Brake fluids have been continually improved, especially in terms of boiling point, starting from the SAE J 7OR3 specification of the 1960s. It is now being widely recognized that water absorption by brake fluids causes them to deteriorate in service after 2–3 years. Owing to the compactness of European cars, brake temperatures have been steadily trending upward for the last 20 years, so boiling points for brake fluids have had to follow suit. Typical boiling points in use in Europe are now 220–2508C, which are too high for the previous DOT 3 (U.S. Department of Transportation) specification; 2208C is the minimum requirement to meet the later DOT 4 specification. DOT 4 fluids are formulated to give greater "in-service" stability, especially with regard to water absorption. There has been a major swing to DOT 4 fluids in the last 5 years in Europe, but not in the United States.

With air-conditioning, and refrigeration systems, some of the newer refrigerants, R134A and R125B introduced as replacement for chlorofluorocarbons (CFCs), are causing difficulties for previously used refrigerator oils, such as naphthenic mineral oils, alkylbenzenes, and poly(α-olefins), which are not compatible. Since the early 1990s, vehicle manufacturers have progressively switched to polyalkylene glycol or ester-type fluids.

The types of hydraulic fluids, shock absorber oils, and greases used in European vehicles have changed little in the last few years, except for some of the chassis lubricants used on European trucks. Some OEMs and users, particularly in the more environmentally sensitive countries, are now using ester-based biodegradable chassis lubricants, to allow for the inevitable wash-off while driving through rain and heavy spray.

Copyright © 1999 Marcel Dekker, Inc.

IV. TRENDS IN THE AUTOMOTIVE INDUSTRY IN EUROPE

A. Manufacturers and Competitive Forces

1. Production of Vehicles in Western Europe

Western Europe is the world's largest car market, ahead of North America, and is the third largest truck and bus market in the world, as indicated in Table 7. In terms of the total numbers of vehicles on the road, western Europe had 35.3% of the world's cars and 15.9% of the world's (trucks and buses. In addition, central and eastern Europe (including the CIS) had 6.0% of the world's cars and 8.1% of the world's trucks, as shown in Table 8.

The major producer countries of cars, trucks, and buses in western Europe are Germany, France, Spain, Italy, and the United Kingdom, as shown in Table 9. While Germany produces more cars than the other four countries, Spain produces more trucks and buses than either France or Germany, and France leads Germany in truck and bus production.

Production and sales of cars in Europe, unlike the rest of the world, involves mainly regional car manufacturers. Volkswagen, Peugeot-Citroën (PSA), Renault, and Fiat had a combined market share of 49.5% in 1997, down slightly from 50.2% in 1996, as shown in Table 10. These companies are primarily European producers, being comparatively weak in the United States and Japan, the other big carmaking regions of the world. Less than 30% of their sales are in markets outside Europe. Volkswagen is strong in Mexico, parts of South America, and China. PSA and Renault have developed, or are developing, sales in South America and Africa, but they depend mainly on their sales in France. While Fiat has a strong position in South America, as well as Poland and Turkey, it still remains heavily dependent on Italy.

In contrast, the world's vehicle industry outside Europe is dominated by five companies. General Motors (GM), Ford, Toyota, Nissan, and Honda control more than 81% of the market in North America, 68% in Japan, 85% in the Pacific Rim, and around 60% in South America. As a whole, the top five companies are estimated to account for more than 75% of all the vehicles sold outside Europe. Within Europe, however, it remains starkly different. In 1997 the top five manufacturers accounted for only 31 % of new passenger car sales, and almost all of that came from the two big North American firms, GM and Ford.

The focus of the main European carmakers on their home markets is a weakness. While they may have a large market share of a large region, they have a high cost base and face the prospects of little or no long-term growth in European markets. Additionally, the trade barriers in the EU will fall in 1999, making European manufacturers more vulnerable still to globally competitive firms. European vehicle makers have known since the late 1980s that their position

Table 7 World Car Sales: 1992–1998

	Sales ($\times 10^6$)			
Region	1992	1994	1996	1998[a]
Western Europe	13.46	11.78	13.44	14.20
North America	9.26	10.46	9.96	10.13
Central and South America	1.55	1.84	2.06	2.26
Asia–Pacific	6.74	7.37	8.45	8.79
Others[b]	3.04	3.50	4.01	4.29
Total	34.05	34.95	37.92	39.67

[a] Forecast.
[b] Central and eastern Europe, Africa, and the Middle East.
Sources: Society of Motor Manufacturers and Traders, *The Financial Times*, Pathmaster Marketing.

Copyright © 1999 Marcel Dekker, Inc.

Table 8 World Vehicle Population: 1996

Region	Number of cars ($\times 10^6$)	Number of Trucks & Buses ($\times 10^6$)	Total ($\times 10^6$)	% of Cars	% of Trucks and buses	Population ($\times 10^9$)	People per car
Western Europe	163.21	23.47	186.68	35.32	15.90	385.28	2.36
Central and Eastern Europe	27.90	11.99	39.89	6.04	8.12	362.48	12.99
North America	168.82	55.75	224.57	36.53	37.76	386.24	2.29
Central and South America	16.67	5.32	21.99	3.61	3.60	386.32	23.17
Asia	62.59	41.77	104.36	13.54	28.29	3116.50	49.79
Middle East	8.75	4.20	12.95	1.89	2.84	281.89	32.22
Africa	7.06	3.43	10.49	1.53	2.32	618.19	87.56
Pacific	7.11	1.72	8.83	1.54	1.16	27.59	3.88
Total	462.11	151.79	609.76	100.00	100.00	5564.49	12.04

Sources: World Automotive Market Report, 1997–98; Pathmaster Marketing.

Copyright © 1999 Marcel Dekker, Inc.

Table 9 Production of Vehicles in Western Europe: 1994–1996

Country	Type	Cars ($\times 10^3$)			Trucks and buses ($\times 10^3$)		
		1994	1995	1996	1994	1995	1996
Austria	Production	0.0	0.0	0.0	52.5	68.4	106.1
Belgium	Production	408.5	385.9	238.1	89.2	82.5	70.1
	Assembly	793.5	782.5	776.6	0.6	21.7	19.8
Finland	Production	17.9	21.4	28.6	0.7	0.6	0.4
France	Production	3,175.2	3,052.3	3,147.6	383.2	422.4	443.0
Germany	Production	4,093.7	4,362.0	4,539.6	262.5	307.2	303.0
Greece	Assembly	5.0	5.3	5.7	0.9	0.7	0.5
Italy	Production	1,340.9	1,422.4	1,318.0	193.6	244.9	227.3
Netherlands	Production	92.0	100.4	145.5	22.7	32.0	32.9
Portugal	Production	0	41.2	125.9	8.8	8.9	9.3
	Assembly	37.8	32.0	26.8	77.0	75.4	71.1
Spain	Production	1,821.7	1,958.8	1,941.7	320.6	375.0	470.6
Sweden	Production	353.0	387.7	367.8	82.0	102.5	95.4
Turkey	Production	212.7	233.4	197.6	53.2	87.9	125.8
United Kingdom	Production	1,466.8	1,532.1	1,686.1	227.8	233.0	238.0
Total	Production	12,982.4	13,497.6	13,736.5	1696.8	1965.3	2122.9

Sources: National Automotive Manufacturers' Associations, company reports, Pathmaster Marketing.

was weak, their costs too high, and their products uncompetitive, so they have had more than a decade to make themselves internationally competitive, to cut costs, improve quality levels, and build a robust global market share. Instead they have, for the most part, hidden behind protectionist walls and extracted high profits—for example, from growth stimulated falsely in France and Italy, through incentive schemes to buy new cars.

Table 10 Market Shares of Car Manufacturers in Western Europe: 1992–1997

Manufacturer	Market share (%)					
	1992	1993	1994	1995	1996	1997
BMW group[a]	3.3	3.2	6.5	6.3	6.2	6.2
Fiat group	11.8	11.1	10.7	11.1	11.2	12.0
Ford	11.2	11.5	11.8	11.7	11.6	11.3
General Motors	12.4	13.0	13.0	13.0	12.5	12.1
Honda	1.3	1.4	1.4	1.5	1.5	1.6
Mercedes-Benz	3.0	3.1	3.5	3.4	3.6	3.6
Nissan	3.2	3.5	3.1	3.0	2.9	3.0
Peugeot-Citroën	12.2	12.3	12.8	11.9	11.9	11.2
Renault	10.6	10.5	10.9	10.3	10.0	9.1
Toyota	2.5	2.8	2.6	2.5	2.6	2.8
Volkswagen group	17.5	16.5	15.8	16.7	17.1	17.2
Volvo	1.5	1.5	1.7	1.8	1.6	1.7
Others	9.5	9.7	6.1	6.7	7.3	8.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

[a]BMW purchased the Rover group in 1994.

Sources: *The Economist, The Financial Times*, car manufacturers, Pathmaster Marketing.

Copyright © 1999 Marcel Dekker, Inc.

Vehicle sales in western Europe were forecast to have risen by 3.3% in 1997, to 14.9 million units. The car market grew by an estimated 3.1 % to just under 13.2 million while the commercial vehicle sector grew by a more healthy 5.3%. Despite the apparent growth, however, Europe's vehicle market is essentially stagnant. As indicated above, many of the new-vehicle sales in the last few years have been artificially stimulated through incentive schemes, first in France in 1995 and 1996 and then in Italy in 1997 and 1998, to replace older, more polluting cars with new, fuel-efficient ones. The total number of vehicles sold in Europe in 1997 was almost identical to the number sold in 1990. The compound annual growth rate for Europe's vehicle market in the last 8 years was 0.0%.

In Europe, despite the convenience of the car and the dependence on trucks for moving freight, vehicles are increasingly becoming a target: a problem to be solved, not a life-enhancing benefit to be exploited, as in the past. Pollution, congestion, too many roads, and too many accidents are making more people rethink their attitudes. Demographic and social pressures may also change the patterns of vehicle demand. As Europe's population ages, the demand for health care and pensions will rise. Under tight economic controls, unemployment is expected to remain a serious problem, too. With a growing number of dependents, the total amount that governments spend on pensions and welfare will continue to rise. This will mean higher taxes and, for job holders (the largest proportion of new car buyers), lower disposable incomes. Together with growing environmental pressures, this decrease in income is likely to encourage people to either buy smaller, more utilitarian, cars or to use public transport more often.

The trend toward smaller and fewer cars is likely to be accelerated by European governments, which are expected to tax vehicles, emissions, and fuels more heavily, and to institute progressive bans on vehicles from some city centers, reducing their amenity value. The current U.K. government, in a change from the previous firm commitment to motor vehicles, has cut the road building program and is giving a greater emphasis to public transport. Moreover, many countries no longer favor out-of-town shopping centers, a policy shift that has slowed further development in this area. There are plans to improve air quality in many cities by targeting motor vehicles, which are seen as the main source of air pollution. Local councils are being encouraged to ban vehicles when pollution limits are breached and to discourage car commuting by increasing the provision of public transport, increasing the costs of parking, and reducing the number of parking spaces available.

With a gradual shift toward more flexible working practices in Europe, a growing but still small percentage of the population has begun to work at home, some for 1 or 2 days a week, and others for longer. The impact of this shift will rise steadily, because people who work at home for even one day a week use their cars for commuting 20% less than before. Even with as little as 5% of the population working in this way, the annual demand for cars will be affected because the replacement cycle will become longer.

The Internet is also having an impact on the car market in other countries, notably the United States. As well as changing the role of traditional dealers, the Internet has begun to affect the prices of cars by creating what economists call "perfect knowledge," a condition that makes it easier for car buyers to know the prices of cars almost anywhere. Thus a pickup dealer in the northwestern United States cornered the market for Dodge Ram sales by advertising his vehicles at the lowest possible prices, showing that with perfect knowledge, prices tend to fall to their lowest economic level. This new paradigm has serious implications for whole industry, but particularly for dealers.

While few of these pressures are likely to affect car demand to any considerable extent in the short term, the ending of the incentive scheme in Italy, which boosted the market there in 1997, is likely to be offset by replacement demand as many of the vehicles sold during the

Copyright © 1999 Marcel Dekker, Inc.

"bubble years" of the late 1980s and early 1990s come up for renewal. Even so, the slow pace of economic growth in Europe means that new car registrations are expected to rise by only 0.2% in 1998. Thereafter, the market is expected to begin to fall back, initially following its usual cycle. Sales are projected to drop by 1.4% in 1999 and then by 3.6% in the following year as environmental pressures and controls on vehicles ownership and usage begin to have an impact.

Beyond 2000, the market for vehicles in western Europe is expected to fall back progressively. This trend will be driven by the changing patterns of use and a gradual drift away from passenger cars as the primary means of personal transport, driven by legislation. This is most likely to affect the most environmentally conscious markets, such as the Netherlands, Austria, Switzerland, and Germany. In other markets, including those where car penetration is lower, or alternative forms of transport are less developed, such as Finland, Sweden, and Greece, vehicle demand will continue to grow, certainly for a limited period. The demand for light commercial vehicles should also continue to expand as the economy cycles upward again and the trend toward "home deliveries" increases. Even then, in many markets, such as those in Italy, the United Kingdom, and France, vehicle sales as a whole are expected to stagnate because of saturation or weak economic performance.

While the "car mentality" of Europe's citizens will take some time to adapt, the effects of these changes, together with modest economic growth rates, are likely to limit the demand for new cars steadily. By the early 2000s, registrations of new cars in the region are expected to begin to fall gradually, like the parc. The parc in Europe is already stable in terms of the number of cars per head of population, and the annual growth has been slowing for almost a decade, except in 1991 during German unification.

2. Trends and Prospects for European Vehicle Manufacturers

Western European vehicle manufacturers have been trying for several years to work out an appropriate response to forecasts of little or no growth in their home markets. When the trends became obvious, many invested in the developing markets in the hope of finding growth there. Yet these markets have proved highly competitive and volatile as evidenced by the economic crisis emanating from the Asia–Pacific region. They also began to squeeze costs out of the suppliers of vehicle components, as discussed in a later section. Now, they are launching a series of smaller cars and are lobbying to slow the pace of policy reform.

The Volkswagen group, which includes Audi, SEAT, and Skoda, was the leading carmaker in western Europe in 1997. Despite tough competition and the growth in Japanese car sales, the company is expected largely to maintain the significant lead it had over its rivals for many years to come. Volkswagen is the dominant supplier in the largest market, Germany, and has an increasingly strong position in many other countries through sales of its own vehicles and those of its subsidiaries. The company is also now well ahead of its nearest competitor, Opel. Indeed, the gap is so large, at 5.1% of the market (around 673,000 cars in 1997) that it would probably take a serious error by Volkswagen or an acquisition by Opel to close it.

In April 1998 Volkswagen confirmed plans to challenge the primacy of Mercedes-Benz in luxury vehicles with at least two high-powered models. An eight-cylinder version of VW's new Passat family saloon will be followed by a limousine built on the basic engineering structure of the next A8 luxury model from Audi. The "Passat-plus" and the limousine, which will be powered by a new V12 engine, could spawn various derivatives to reinforce VW's move into Mercedes-Benz territory. The company emphasized that the move into the luxury market would not distort or damage its image as a manufacturer of affordable volume cars, saying that VW needs to be a pyramid, with its brand unconstrained by any definitions from the past. VW

Copyright © 1999 Marcel Dekker, Inc.

recognizes that a successful move upmarket will depended on creating a sense of expectation among motorists and on accurate timing. While the company's image in Asia is already strong enough to support such cars, the process will take longer in Europe, where VW will have to ensure that dealers are able to offer an appropriate standard of service.

Earlier in 1998, VW forecast that sales in the US would soar to 180,000, from 138,000 in 1997. Sales in the first 2 months rose almost 30%, following immense interest in the New Beetle, which was launched at the Detroit motor show in January. U.S. sales would be boosted by better availability of the Passat and continuing strong demand for the Jetta, while production of the New Beetle in Mexico would be increased to 160,000 a year from 130,000. The original plan was to make 100,000.

The multibrand strategy adopted by Volkswagen had given the group increasing dominance over Europe's new-car market, even without the Rolls-Royce, Lamborghini, and Bugatti brands that were acquired in May 1998. According to ACEA, VW achieved an 18.1% share of the European car sales in April 1998, more than 6 percentage points clear of its closest rivals Fiat, (11.6%) and Peugeot-Citroën (11.1%). Sales in May rose by a year-on-year rate of 9.8%, exactly double that of the market as a whole. Growth for the group was led by its Spanish SEAT subsidiary, with sales for the month up 22.7%, and Skoda of the Czech Republic, up 15%. VW now appears to have broken up the oligopoly of western Europe's new-car market, in which VW, Fiat, Ford, General Motors, Peugeot, and Renault have held broadly similar market shares for two decades. The acquisition of the three luxury carmakers will add little to VW's unit sales, initially no more than 3000 a year. However, it will give the group the broadest coverage of all sectors of the new-car market, and the "halo" effect of owning some of the most prestigious names in the global motor industry.

General Motors, with a 12.1% share of the European car market in 1997, held second place, as it has done since it ousted Fiat from the position in 1992. Until 1994 Peugeot was close behind, but the gap between the two companies has increased as a result of poorer performance by Peugeot since 1994. PSA controlled an estimated 11.2% of the market in 1997, with the recent drop due to a sharp fall in sales in France since the ending of the incentive scheme. In view of the number of new models Opel will launch shortly, General Motors is expected to remain firmly in second place for the next few years.

In 1995 Fiat had fallen to sixth in the league of the top six companies selling passenger cars in Europe, a humiliating decline after so many years near the top. Yet in 1997 Fiat improved its position and moved up to third place. However, the latest performance is due to the incentive scheme in Italy, where most of the company's sales are based, so its success is expected to be short-lived as the scheme is phased out. Fiat may maintain third place, because the sales and shares of Ford, PSA, and Renault are expected to fall too, as they have done for the last few years. Ford's sales in its largest market, the United Kingdom, will continue to suffer from the growth of the Japanese transplants and the move away from fleet vehicles. The company is also expected to lose share in other markets as its controversial model renewal program encounters fierce competition, notably in the midrange sector from Passat, and in the lower medium sector from the latest respected replacement for the Golf. Similarly, PSA and Renault are expected to come under increasing competitive pressure in France. With the pressure on prices and margins, as well as the drop in sales forecast for these companies, each is expected to cut costs and employment progressively. Fiat and Renault may even begin to seek partnerships with other producers.

In January 1998 Peugeot-Citroën announced plans to build three-quarters of its vehicles on new platforms by 2002 and to raise the proportion of its cars sold outside Europe to 25% in coming years, from about 16% at present. The announcement came during the signing of an agreement to build a new $600 million plant in Rio de Janeiro State in Brazil. The plant is

Copyright © 1999 Marcel Dekker, Inc.

scheduled to begin production in about 2000 and will eventually be capable of producing 100,000 Peugeot and Citroën vehicles a year.

The number of platforms the company uses will be cut to three, from seven at present, as part of a sweeping industrial reorganization. Eventually all six Peugeot-Citroën factories with a capacity of more than 1000 cars a day will specialize on a single platform common to both the Peugeot and Citroën marques. This is seen as a way of producing in volume cars in an effective and productive way. By mid-1998, the Mulhouse site in eastern France will stop making the Peugeot 106 and switch to a new model, expected to be the keenly awaited replacement for the Peugeot 205. Production of the 106 would move to Aulnay, outside Paris, which currently specializes in Citroën's very similar Saxo model.

Peugeot-Citroën has spent £100 million to modernize its U.K., plant in Ryton to build right-hand drive versions of its new 206 hatchback for the U.K. and overseas markets. Although similar-sized Peugeot and Citroën models have been developed off common basic engineering structures for some years, they have until recently been built at separate factories. Factories will both versions of future vehicles to cut costs. Producing an eventual Citroën sister car to the Peugeot 206 could lift Ryton's output to about 200,000 cars a year. Last year the plant built 90,000 Peugeot 306 models. Production of 306s is now being transferred back to France to accommodate the 206. Output at Ryton could be easily stepped up by adding extra shifts. The plant which has a production staff of 3000, currently works on a 4-day week, using the so-called double day shift.

The overall share of Japanese carmakers in Europe peaked in 1991 at 12.2%. Since then, the appreciation of the yen and the drop in demand in their largest markets (the United Kingdom and Germany) resulted in their share falling to 10.5% in 1996. Japan's smaller suppliers, such as Suzuki, Daihatsu, Subaru, and Mazda, were affected particularly badly. With the fall in value of the yen and heavy cost cutting, the share of Japanese car manufacturers began to recover again in 1997, just as it did in the United States. With the high costs that burden many European companies, and further drops in the yen's value, this trend is expected to continue. Toyota and Honda are also expected to build their position through additional investments in regional production. With greater liberalization, all the Japanese firms are expected to focus much of their attention on the large but traditionally closed markets of France and Italy.

Given the prospect of consolidation in the automotive industry, both Saab and Volvo face common challenges to their future as independent manufacturers. Volvo has established an alliance with Mitsubishi, in which the companies jointly produce midrange cars in the Netherlands. But Mitsubishi has been described as vulnerable following the announcement of the Daimler–Chrysler merger and may not be the ideal partner for Volvo to extend its global reach. Volvo believes it has drawn up a strategy with which it feels confident, and the Swedish firm is neither threatened nor surprised by the Chrysler–Daimler deal.

Volvo's car division will rely on just two platforms, the S80 large car and S40/V40 medium-sized model, and will offer variants according to customer tastes. If the S80 is well received and Volvo proceeds with plans to sell the S40/V40 in the United States, rising demand could help it reach its critical production target of 500,000 by 2000. A credible top-of-the-range model would also help Volvo narrow the margin between itself and rivals such as BMW and Mercedes. At the same time, the company says it will use its cash pile to develop divisions such as construction equipment and trucks to reduce its dependence on cars.

Saab, 50% owned by GM, cannot fall back on other businesses, but the company is confident it will break even in 1998 and has even greater ambitions than Volvo. Although using GM components on its 900 model proved to be ill-judged, Saab is now working on three new platforms in cooperation with GM. Assuming that GM acquires outright control of Saab from Investor in 1999, when put and call options between the two companies mature, the future of the

Copyright © 1999 Marcel Dekker, Inc.

company could, ironically, look more secure than that of Volvo in a rapidly consolidating industry. Saab's current objective is to make money, although attention is now being given to products after 2000.

In May 1998 Volvo announced plans to cut its supplier base by about three-quarters in an attempt to drive down purchasing costs and improve operating margins. The company, which sources car components from some 400 "tier one" suppliers, hopes to reduce that total to about 100 by 2005. The plans are the latest step of the Volvo 2000 campaign, a strategy announced in December 1997 to lift productivity by 5% per year and increase annual sales by 10% to SKr250 billion ($32 billion). The company is not satisfied with current operating margins of 4%, and cutting the supplier base is one way to reduce its SKr100 billion purchasing budget by about 9% per year and lift operating margins to between 5 and 7%.

As part of the cost-cutting program, Volvo is switching from dual sourcing to single-sourced car parts, with suppliers being more responsible for preassembling component modules. Volvo underlined the benefits of that strategy when it launched its new S80 large car, construction of which relies on 70 fewer suppliers than the S90/V90 range it is replacing. The company aims to use no more than 150 suppliers on the S80, and in future could end up with only 100 suppliers across the large car division. In developing the S80, estimated to have cost SKr30 billion, Volvo has farmed out development work and preassembly of subsystems such as brakes and seating to single suppliers. Volvo hopes to forge deeper partnerships with such suppliers, leading to lower costs and more efficient delivery and assembly times.

In June 1998, Honda Motor Company announced that it would build a new car range at its Swindon plant, from 2002, bringing its total investment in the United Kingdom to £1.15 billion. The expansion of the Swindon plant will cost £450 million, which includes £200 million for the development of the next-generation Civic from 2001 and £120m million for the improvement of manufacturing facilities. By 2002, the plant will be able to produce 250,000 cars annually. The model built at Swindon will be entirely new, designed for Europe, and not based on Honda's latest J-series small vehicles, the first of which went on sale in Japan earlier in 1998.

European manufacturers of trucks and buses have been more willing than their carmaking colleagues in recent years to enter into joint manufacturing arrangements. In 1997 Renault has announced a deal with Daf to cooperate on truck cabs and a full-scale joint venture with Iveco on buses and coaches. Early in 1998 Renault hinted that it could be interested in working with MAN. Until late 1996, Renault and MAN were negotiating to develop small truck engines and heavy rear axles together, but the discussions were stopped because neither company saw any financial advantages from the cooperation. But MAN was not asked to participate in the bus deal with Iveco.

MAN believes it can succeed alone, noting that its share of western European sales of trucks of more than 6 tons exceeded 13% in 1997, up from 12.8% in 1996. This puts the company firmly as Europe's number-three producer of large trucks, behind Mercedes-Benz and Ford. But while Europe accounts for the bulk of MAN's present sales, the group is investing heavily in new production sites to feed emerging national markets and act as satellites for regional demand. The first is in Turkey, where MAN gained full control in 1997 of MANAS, a local truck and bus manufacturer with which it has been associated since the mid-1960s. MAN has spent heavily to expand the company to supply the large Turkish market and as a regional base for parts of the former Soviet Union, the former Yugoslavia, the Middle East, and parts of Asia.

The company's second big investment has been in Poland, where it decided in 1996 to build a DM25m plant after failed attempts at local joint ventures. The factory, which was opened in December 1997, builds low-floor city buses for the local and neighboring markets, assembles trucks from kits from Germany, and manufactures important subcomponents for MAN's big Salzgitter truck and bus plant in northern Germany. MAN's latest venture, at Minsk in Belarus,

Copyright © 1999 Marcel Dekker, Inc.

involves two majority-owned joint ventures to build and sell trucks, almost all to Russia, with which Belarus has a customs union.

In April 1998 Paccar acquired Leyland Trucks, the United Kingdom's last independent manufacturer, in a deal that reinforces Paccar's assault on Europe after its $802 million (£480 million) purchase of Daf Trucks, the Netherlands-based maker of heavy trucks, in November 1996. Paccar, which is the world's fourth biggest maker of trucks of more than 6 tons, also owns Foden and controls the Kenworth and Peterbilt brands in the United States. The deal could accelerate rationalization among Europe's remaining truck manufacturers. Volkswagen, Europe's biggest carmaker, which builds trucks in South America, is seeking to expand in commercial vehicles. Scania, the Swedish heavy truck specialist, is poised to move into lighter trucks, and Volvo is developing links with Mitsubishi of Japan.

3. Suppliers of Components to the Car Industry

Since the early 1990s, vehicle manufacturers in Europe, the United States, and Japan have sought to cut costs, shorten new-product lead times, and simplify manufacturing processes by devolving to component suppliers much of the burden of designing, developing, and manufacturing entire subsystems, which the carmakers can then install quickly and simply on the production line. Examples of such subsystems include dashboard modules, complete wiring harnesses, and axle assemblies. Carmakers have asked component suppliers to follow them down the path to globalization and to set up components supply operations wherever in the world the carmakers require.

With parts and materials accounting for about two-thirds of the cost of a vehicle, even a small discount can make a big difference given the volumes involved. Pressure on pricing, often combined with the need to seek economies of scale, the reward of bigger, long-term orders, and the threat of being potentially removed from the carmakers' supplier lists have encouraged many suppliers to respond positively. Part of the response has been through acquisitions and mergers, so that suppliers have started to reshape the supply chain for components. In some key sectors, such as braking systems, there are now only a small number of suppliers with the required global and technical capabilities.

Combined sales of the components suppliers, around $250 billion in 1997, are growing more rapidly than the turnover of the vehicle makers themselves, and on current trends will continue to do so. Carmakers' concerns have been increased by the realization that whereas initial consolidation involved companies engaged in essentially the same business, now the leading component suppliers are starting to forge alliances across traditional sector boundaries. For example, in 1997, Breed Technologies, one of the bigger U.S. companies involved in vehicle safety systems, particularly seat belts and air bags, announced a joint venture with the automotive operations of Siemens. Specifically, Breed will pool its physical restraint system know-how with Siemens's expertise in advanced sensor electronics. Also in 1997, the U.S. components group Federal-Mogul acquired the T&N, a U.K. firm having expertise in a number of technologies in which Federal-Mogul's know-how was lacking. Varity Corporation has sold its Perkins diesel engines subsidiary to Caterpillar, creating the world's biggest diesel engine supplier, which now supplies virtually every size of diesel engine in the global market.

In 1997 global overcapacity and poor prospects for growth forced the world automotive industry into more than 700 merger or acquisition deals with a value of about $28 billion. Europe was the main focus of the rationalization and is likely to be the subject of continuing upheaval. The declared value of merger and acquisition activity in Europe jumped 50% in 1997, from $10 billion to $15 billion, covering 371 individual transactions. In North America and Europe, acquisitions in the components industry were focused strategically on acquiring the ability to supply complex systems for vehicles, rather than parts. The $1.2 billion acquisition by the Peugeot-Citroën group's Ecia components subsidiary of seat-maker Bertrand Faure, for example,

Copyright © 1999 Marcel Dekker, Inc.

has given Ecia the critical mass to compete globally. More similar deals will emerge over the near future as North American and European component groups target each other and lower cost manufacturers.

Electronics systems, the use of which has already risen to exceed in value the steel content of the average car, and which is still growing at around 20% per year, illustrate the diminishing proportion of revenue from a finished car going to the carmaker. As Ford noted in early 1998, some cars already contain more computing power than was deployed in the U.S. moon landings. The future added-value deriving from advanced transport communications technology will be much higher yet, as installation becomes widespread of high value systems such as satellite navigation, automatic crash location and emergency signal sending, collision-avoidance radar, and even on-board Internet hookups. Large informational technology companies such as Microsoft and Intel are also seeking a slice of the automotive cake and are now adapting games, Internet, and other technologies for integrating into car systems.

While carmakers worry about their relationships with suppliers, components groups are also finding cause for concern. Vehicle manufacturers are focusing on greater savings by using an even smaller number of vehicle platforms, intended to be for global use. However, the idea that global vehicle platforms mean global components, with all the implied benefits of scale economies and cost savings in research and development, has turned out to be a rather simplistic one. Market tastes, different governments' legislation in areas such as safety and emissions, and other factors still require vehicle makers to differentiate their platforms between regions, with substantial knock-on effects for components suppliers. Thus it is rather difficult to forecast market demand, based on how many consumers will pay for a given feature.

For example, Ford announced in 1996 that almost all its vehicles would be fitted with side air bags, which encouraged General Motors and Chrysler to do the same. As a result, Lear, Johnson Controls, and other big suppliers of seats started to develop complex and expensive design and engineering programmes for side air bags. Then came the "deadly" air bags furor in North America and what looks like a retreat by all three U.S. carmakers on side air bags, while in Europe, where air bag specifications differ, there has been no such controversy, and fitments of side air bag seats are rising rapidly. It would appear that "global" seating systems are not yet a reality.

Even something as seemingly simple as a manual seat adjustment system cannot be assumed as a global item. While many Americans prefer a lever actuator for the seat recliner, many Europeans prefer a rotating knob. Regional taste, it seems, has a direct impact on design requirements for the same platform, even though installation of the feature is the same for different regions. Carmakers are worried by the prospect of fewer, increasingly powerful, and potentially less compliant component suppliers, whose products account for an ever greater proportion of the value of a finished car.

4. Consolidation in Vehicle Manufacturing in Europe

Vehicle manufacturers in Europe have been on the edge of a competitive consolidation for several years. The industry and Europe's governments, however, have avoided this through denial, the maintenance of trade barriers and by falsely stimulating markets though incentives. These have more or less maintained profits and sales volumes, but little has been spent on improving competitiveness, increasing quality levels, or cutting costs. Instead, a great deal has been invested in brand development, marketing, and product proliferation. As a result, Europe's car industry is highly dependent on the image of its products.

The industry, however, now faces a series of problems: there are no more countries willing to offer incentives; buyers for new cars are becoming fewer; competition is set to intensify;

Copyright © 1999 Marcel Dekker, Inc.

protective barriers are about to fall; environmentalists are winning the battle for the minds of consumers; and governments are increasingly unwilling to promote the car. Perhaps most important, a car's image may be becoming less powerful in the minds of buyers, so that cars are becoming more like commodities, to be judged mainly on price. Europe's vehicle industry may have held off consolidating for more than a decade, but it seems unlikely that such a move can be postponed much longer.

The merger between Daimler-Benz and Chrysler, announced in May 1998, may provide the catalyst that starts a wholesale consolidation of Europe's vehicle manufacturers. The merger will create the world's fifth-largest car company by volume, with annual revenues of around $130 billion, and one that matches the global reach of the top four car companies. Detroit will no longer consist of two global giants, Ford and General Motors, and one regional carmaker, Chrysler. In North American, Chrysler, which has been weak in passenger cars, will be able to draw on the engineering expertise that has produced Daimler-Benz's unequaled Mercedes cars.

In Europe, the merger is likely to have an even greater significance, since it probably means that the independence of the rest of Europe's regional car groups cannot last. Renault, Peugeot-Citroën, Fiat, Volvo, and even BMW are now likely to be busy considering their strategic options. All the European carmakers will now face a head-on competitor, Daimler–Chrysler, with its own new small cars and the firepower of its U.S. partner. While the merger is unlikely to bring a flood of new small cars into Europe, me deal proves that Daimler is determined to become a true volume producer across the whole range, with production heading for more than 2.5 million cars a year. France and Italy no longer can patronize the German company's efforts with the small A-class car, which had to be reengineered after it turned over in a "moose test," and the upcoming wacky Smart car, which is small enough to put in the trunk of a big Mercedes.

Daimler–Chrysler will have an impressive range of models. Mercedes-Benz produces some of the best luxury cars in the world, plus some innovative small ones just coming to market and several untried commercial ventures. Chrysler's saloon cars are outgunned in America by Ford and GM, but its average profit for each vehicle is the highest of the Big Three thanks to its strength in minivans and jeeps, where margins are fattest. Chrysler clocked profits of $1468 for each sale in 1997, compared with Ford's $1000 and GM's $683. Such margins appeal to Mercedes, which makes $1561 on its mainstream C-class cars and three times that on its luxurious E-class cars. Moreover, Mercedes does not have strong products of its own in the minivan and jeep class, though its new American-built off-roader is promising.

Although a European industrial company has never made an acquisition on this scale, the most remarkable feature of the Daimler–Chrysler deal is not its size but its unique structure, spanning two continents. American, Japanese, and some European carmakers have been manufacturing in different locations around the world for many years, but one of America's prime industrial companies has never been run at least partly from abroad.

However, the merged company faces two key problems. The first concerns the new group's weakness in Asia and Latin America. While these are relatively small markets, they are the ones where much of the future growth is expected, despite Asia's recent troubles. Although Daimler has recently retreated a bit in China, the new carmaker will at some point have to expand in Asia, possibly by forging links with Nissan, which was apparently in talks with Chrysler about a possible takeover. But the merger is likely to prompt mergers by other vehicle manufacturers, so the opportunities for expansion in Asia may become fewer.

The second, and bigger, question is whether the two companies can make the merger work. Some industry observers have noted that while the logic of the merger is faultless, putting such different companies together could be difficult because of the differences in their cultures; (i.e., dissimilarities in how the two companies think and act and in what drives their decisions).

Copyright © 1999 Marcel Dekker, Inc.

Daimler–Chrysler is to have two bosses, Daimler's boss, Jürgen Schrempp, and Chrysler's, boss Robert Eaton, and will be run from two headquarters, one in Stuttgart and one in Michigan. Such arrangements are notoriously difficult to implement and manage.

Both companies are successful and complementary, and some savings, such as in joint distribution, are likely to be possible. But realizing these savings will stretch the talents of both teams of managers. Big expensive cars that offer a superb driving experience on autobahns are not the same as big cheap cars that most Americans prefer to drive. Chrysler is a lean North American producer, which buys 70% of its added value from outside; Daimler is a fully integrated German maker of luxury cars, famed for its world-class design and engineering. Chrysler has come back from the brink of bankruptcy twice in recent years. It survives thanks only to its distinctive and lean way of involving suppliers in its innermost thinking. Chrysler has come as close to producing cars to the legendary Toyota lean standard as any other company. Daimler will be tempted to impose its methods on Chrysler, but the German company may have more to learn from Chrysler's manufacturing skills than it realizes.

Consolidation among Europe's vehicle manufacturers will come eventually, due to two relentless pressures. The first is the immense fixed costs of developing and manufacturing vehicles, which means that continuing to make profits from cars increasingly goes with making lots of them. In future, more customers will want to drive something that looks different from other cars, so the most profitable manufacturers will be those that satisfy this urge for individualism, but from one basic design. Volkswagen and Fiat have developed plans to build many models from a single chassis and to sell them in many countries.

The second pressure comes from the industry's persistent overcapacity at a time when prices are being driven down relentlessly by global competition. The world's car plants could build around 30% more cars than they do. Even before the recession of 1997–1998, Asia's overcapacity approached 35%, and western Europe and South America are little better. Plants are busy in North America, but cheap imports push down prices. As in many other industries, carmakers are very reluctant to cut capacity. A few plants have closed recently, but overall capacity has, if anything, increased, notably in Europe. Although Renault's decision last year to shut its Vilvoorde plant in Belgium, and moves by Ford and GM to trim output have had some effect, they have been heavily outweighed by expansion among Japanese "transplants," capped by Toyota's decision in December 1997 to build a plant in northern France for up to 200,000 small cars a year.

U.S. markets have offered some consolation. Five strong years of car sales at or around 15 million units a year and booming demand for beefy sports utility vehicles have alleviated overcapacity among the domestic Big Three and boosted imports from Europe and Japan. But the relative strength of sales in the United States and expanding markets in eastern Europe have not been enough to reduce global overcapacity. Expansions and exports from the new Asian carmakers have not helped either. The arrival of new, low cost entrants has depressed prices. In Europe, analysts expect prices to be squeezed even harder when a single currency starts to expose inconsistencies in national pricing policies and prompts buyers to shop around more.

Even an innovative edge, which previously enabled companies to exploit new markets, is no longer enough. New technology and efficiency gains have cut the time taken to develop a new car to about 2 years, which has sharply reduced the comparative advantage of even the most innovative carmakers. Renault's current margins on its highly popular mid-sized Megane Scenic people carrier will soon be eroded by the launch of copycat cars from other manufacturers.

But car companies have generally shied away from following the example of components in seeking the most obvious way of cutting costs and tackling overcapacity by consolidating among themselves. The takeovers and mergers that have occurred in recent years have almost

Copyright © 1999 Marcel Dekker, Inc.

invariably involved distressed or fringe producers. In the United Kingdom, for instance, the sales of Jaguar to Ford, Rover to BMW, and, most recently, Rolls-Royce to VW, have invariably involved companies too small or too troubled to survive independently. By contrast, mergers of equals in the same region, which would lead to significant capacity cuts, remain rare. Two broad reasons explain that unwillingness. Managements and, sometimes, shareholders, have been reluctant to cede control. The planned marriage of Renault and Volvo, for instance, collapsed as the Swedish group's shareholders became worried about coming under the dominance of a state-owned French company.

Concern about capacity cuts has been the other big reason. This has often been compounded by union opposition to job cuts, tacitly encouraged by governments. Carmaking is a crucial source of employment, both directly and through associated industries, such as components. It is also politically important, so as with other symbols of economic prowess, governments have been keen to encourage carmakers to expand, often with the bait of generous investment grants. Because Chrysler and Daimler-Benz are largely complementary in products and geography, and are both producing highly popular vehicles at virtually full steam, their merger will not require painful plant closures. This means that governments and unions are unlikely to oppose the merger.

Consolidation might have happened some time ago if governments had not been so transfixed by the prestige of having a "national" car industry. Europe tried to keep out Japanese cars with quotas and tariffs. Malaysia built a national car, the Proton, using trade barriers and government subsidies. Countries such as France, Spain, and Italy have also tried to conceal overcapacity by government schemes to bribe people to buy new cars. Attempts to merge across border have sometimes been thwarted by national rivalries, such as between France and Sweden about control a merged company consisting of Renault and Volvo. Attempts to cut costs by closing factories; as Renault did in Belgium, have all too often been hampered by politics.

Where nationalism is muted, the industry has done better. There is less overcapacity in the United States, partly because the government has allowed prices to fall and factories to close. (However, it has still to end some tariffs on, for example, sport utility vehicles). The United Kingdom has seen one carmaker after another pass into foreign hands, yet although there is no large British-owned carmaker, Britain made almost twice as many cars in 1997 as it did in 1980, and its share of the western European market has grown by a third to roughly 12.5%.

So the Daimler–Chrysler merger is not necessarily typical of the deals that will be required to rescue most carmakers from their present distress. In Europe, the prospect of rationalization is additionally overclouded by nationalist interests. Fiat's three attempts over the past three decades to ally with another carmaker have invariably foundered on the question of management control. Talk in France of a merger between Renault and Peugeot-Citroën is invariably quashed by both sides on the grounds that it would be politically unacceptable and would trigger a labor revolt.

Unfortunately, the number of potential deals that minimize the pain while maximizing the potential gains, such as those between partners with sharply differing product ranges, appear to be relatively few. The only alternative is for politicians, manufacturers, and workers to grasp the nettle and accept that matters will have to get a good deal worse before they get better.

It is likely to benefit the whole industry if the merger between Daimler and Chrysler accelerates the demise of national car companies. Nervous politicians should be comforted by the realization that at a time when cars and components all resemble one another, a national identity has become a vital part of the brand. People who buy a Mercedes are buying German engineering and those who buy an Alfa Romeo are buying Italian design, regardless of where the car is built. The key focus of the current and future mergers should be to eliminate the nationalism of carmaking, while keeping the nationality of the vehicles.

Copyright © 1999 Marcel Dekker, Inc.

5. Production of Vehicles in Central and Eastern Europe

Central and eastern Europe are much smaller markets for vehicles than is western Europe, but the potential for expansion is much greater. Production of cars grew substantially in the 1990s, but production of trucks and buses declined slightly, as shown by the data in Table 11. Central and eastern Europe, including Russia, produce less than one-seventh of the cars produced in western Europe, but the recent rate of growth has been between 7 and 10% per year. Currently, the region produces about one-eighth of the trucks and buses produced in western Europe.

The largest manufacturing countries are Russia, Poland, and the Czech Republic, and the biggest companies are Lada in Russia, which produced 681,000 cars in 1996, Fiat in Poland, which produced 307,000 cars in 1996, and Skoda in the Czech Republic, which produced 263,000 cars and 23,000 trucks in 1996. Skoda, part of the VW group, has improved the quality and reliability of its cars to such an extent that it is now winning consumer awards in western Europe and increasing its share of the market in several countries.

The most recent new entrant into the region has been Daewoo, which took control of FSO in Poland in mid-1996. Since then, FSO has narrowed the gap on Fiat and claims that it is poised to overtake it with a new generation of Korean-designed cars that started production in November 1997. Although Poland is central to Daewoo's plans for central Europe, the company has, since the early 1990s, also purchased or partnered with other carmakers in Romania, Uzbekistan, and the Ukraine, as well as commercial vehicle manufacturers in Poland and the Czech Republic.

Daewoo's output in Poland is expected to reach 570,000 units by 2000, making it by far the biggest of Daewoo's foreign operations, accounting for more than one-fifth of the group's forecast production. Some analysts, however, have questioned Daewoo's judgment in buying FSO, which was one of the least efficient of the former communist carmakers. The purchase followed almost 5 years of fruitless talks between the Polish government and General Motors. While GM insisted in tough terms, including shedding many of FSO's 22,000 workers, Daewoo offered a 3-year employment guarantee. The company also agreed to keep FSO's Polonez cars in production and promised to build a new generation of Daewoo cars in the dilapidated plant.

Now, although externally the plant remains a vast sprawl of grandiose buildings designed for many more than the 95,000 cars made in 1997, much of the body and assembly areas have

Table 11 Production of Vehicles in Central and Eastern Europe: 1994–1996

		Cars ($\times 10^3$)			Trucks and Buses ($\times 10^3$)		
Country	Type	1994	1995	1996	1994	1995	1996
Belarus	Production	0.0	0.0	0.0	21.3	21.9	21.1
Bulgaria	Assembly	0.0	1.7	1.7	0.3	0.5	0.5
Czech Republic	Production	153.9	189.5	240.1	29.7	29.4	35.5
Hungary	Production	32.7	42.0	45.7	1.7	1.6	1.6
Latvia	Production	0.0	0.0	0.0	6.6	4.3	4.3
Poland	Production	321.1	393.7	445.0	23.7	28.0	33.3
Romania	Production	80.2	71.0	97.9	5.7	19.9	23.2
Russia	Production	797.9	838.5	871.8	194.2	156.5	136.0
Slovakia	Production	6.0	19.7	30.1	3.0	2.9	2.0
Slovenia	Production	73.9	87.6	89.2	0.3	0.4	0.4
Ukraine	Production	94.2	59.8	9.0	14.5	15.0	15.0
Total	Production	1556.0	1701.8	1828.9	300.8	279.2	272.4

Sources: National Automotive Manufacturers' Associations, *World Automotive Reports*, Pathmaster Marketing.

Copyright © 1999 Marcel Dekker, Inc.

been upgraded for production of the Lanos, Daewoo's new small car. FSO will also assemble the larger Nubira and Leganza and, in 1998, it should start building Daewoo's latest car, the diminutive D'Arts. Daewoo has invested $22 million to refresh the Polonez and production has been additionally boosted by assembling the Tico and Espero. New body and assembly halls are under construction for the updated cars. The company believes the new cars will soak up FSO's surplus labor and turn what many observers thought was a basket case into a success. The plan has been bolstered by the vibrant Polish car market, in which sales of cars and commercial vehicles reached 534,000 in 1997, from 426,000 in 1996 and 296,000 in 1995. Poland was the seventh largest market in Europe in 1997, and is expected be the sixth largest in 1998 and perhaps even the fifth largest in 2000.

FSO is just part of Daewoo's automotive commitment to Poland. The company also owns the former FSL, a commercial vehicles group employing 5000 workers, which is being modernized to build new products under development at Daewoo's Worthing Technical Center in the United Kingdom. Many of the engines will come from Andoria, the Polish motors group with 2000 employees, which is also owned by Daewoo. Some may be shared with Avia, a Czech commercial vehicles group that also is owned by Koreans. Components will be sourced from Polish producers also under Daewoo's control. Some of the subsidiaries may eventually supply Daewoo's other vehicle operations in eastern Europe and the former Soviet Union in a complex production matrix.

However, there has been at least one major problem associated with the developing markets in central and eastern Europe, namely, the trade barriers and tax breaks that distort or discourage free competition. For example, from late 1997 to mid-1998, the EU clashed with Ukraine over tax breaks to AvtoZaZ, a domestic carmaker, and restrictions on used-car imports, which the commission claimed made it virtually impossible for anyone else to sell cars in Ukraine. AvtoZaZ created a joint venture in September 1997 with Daewoo, in which the South Korean company planned to invest $1.3 billion (£780 million) in the next 6 years to modernize and expand AvtoZaZ's operations.

The EU complained about restrictions on imported cars, finalized in April 1998 by Ukraine, including a ban on used cars more than 5 years old or deemed to be worth less than $5000. The import restrictions were introduced after Daewoo asked the Ukrainian government to impose a $2000–$4000 import duty on used foreign cars, after the government had already given the venture special treatment by writing off much of AvtoZaZ's debts and granting tax exemptions until 2008. The moves reflect Ukraine's keenness to ensure that the Daewoo investment can move ahead, in spite of the Korean financial crisis. The $1.3 billion planned investment is equivalent to more than half of the $2 billion total foreign direct investment Ukraine has attracted since 1994.

The EU has warned that failure of consultations to resolve the problem would trigger the dispute settlement procedure under its 1995 interim trade agreement with Ukraine. If Ukraine does not respect any solution agreed through that process, similar to the disputes procedure of the World Trade Organization, the EU has the right to take retaliatory measures. The commission argues that measures aimed at driving competition out of the Ukrainian market and sends a "very negative message" to other potential foreign investors. It added that such violate several clauses of the EU's trade agreement with Ukraine and are contrary to Ukraine's policy of joining the World Trade Organization. At the time of writing, the dispute is still being discussed.

6. Design and Engineering

Europe has always been at the forefront of automotive vehicle design and engineering, and this preeminence has continued during the 1990s. Much of the successful automotive engineering carried out in Europe stems from the very heavy involvement in the United Kingdom, Germany,

Copyright © 1999 Marcel Dekker, Inc.

France, Italy, and other countries in the world's racing car industry, particularly Formula 1 and Indy 500 racing. While these areas are highly specialized and involve comparatively few companies and people, the value of the commercial spin-off from their innovations and developments cannot be overemphasized.

Germany's largest carmakers are planning to work with energy companies and the government to develop more fuel-efficient and environment-friendly vehicles, including cars and trucks that use alternatives to gasoline or diesel engines. In May 1998 the German transport ministry announced a joint initiative to combine know-how and avoid unnecessary costs involved in developing competing technologies. The project, which is supported by VW, BMW, Daimler-Benz and MAN, Shell, RWE, and Aral, reflects the strength of Germany's environmental lobby and concerns about retaining the technical edge enjoyed by the nation's car industry.

The objective of the two-pronged strategy would be to protect Germany's international competitiveness against the background of demands for more environment-friendly transport systems. Initially, the research group would seek to encourage the development of existing gasoline and diesel technology, which is expected to see several manufacturers introducing cars that can travel 100 km on 3 L of fuel or less in the next decade. The participants would then seek to identify objectively, by the end of next year, up to three alternative energy sources on which to concentrate efforts. The ultimate aim would be to agree a joint strategy on new energy technologies selected from a list that includes internal combustion engines running on natural gas or hydrogen, electric engines, or hybrid motors combining a variety of technologies.

Earlier, in December 1997, Daimler-Benz announced that it was investing $420 million in an alliance with Ford and Ballard Power Systems of Canada to produce up to 100,000 cars a year powered by hydrogen fuel cells by 2004. The companies intend to derive the hydrogen for the cells from natural gas. This sourcing would reduce overall emissions of CO_2 from vehicles by 60% and would eliminate most other pollutants, including particulates, completely.

In June 1998 a team of engineers from the University of Sheffield's machines and drives group, Daewoo's technical center at Worthing, and a number of private consultants released the preliminary findings of a study of hybrid propulsion systems for delivery vans funded by the U.K. Department of Trade and Industry. The results indicate that hybrid vehicles, fitted with an electric motor and a conventional engine, could be twice as fuel-efficient as conventional models.

The engineers believe that hybrid vehicles are more likely than electric vehicles to replace diesel and gasoline engines, mainly because they do not need very large, expensive batteries to give them an adequate range. Also vans are likely to be the best market for hybrid vehicles, because they need only a short range and because a company-managed fleet is more likely to be maintained properly. The team first considered what combination of engine/electric motor/ battery a hybrid vehicle would need to match the range, acceleration, and ability to climb gradients of a conventional 1-ton van with a 2 L diesel engine. They calculated that the hybrid van would need only a 1.6 L engine, plus a 45 kW electric motor. It would also have a heavy lead–acid battery and would be about 350-kg heavier than the diesel van.

Because delivery vans stop and start frequently, the advantage of the hybrid vehicle in urban areas is that the battery can be used as a temporary energy store. In the team's hybrid design, the kinetic energy of motion is converted into electrical energy during braking, using the well-understood technique of regenerative braking to recharge the battery. Regenerative braking not only saves energy that would otherwise be wasted, but also allows the internal combustion engine to run more efficiently. Diesel engines are least efficient when the load on them is low, so the electric power source helps to even out the load on the engine. Because hybrid vehicles are more energy-efficient, they will cut pollution. However, the need for the batteries means that hybrid vehicles will be more expensive than conventional ones. Further

Copyright © 1999 Marcel Dekker, Inc.

development should allow repayment of the additional capital cost within a limited time, since operating costs will be lower.

A new U.K. company, Torotrack, previously an operating unit within the British Technology Group (BTG), has designed a revolutionary transmission system that won its creators a grand prix at the European Inventions Competition in Monte Carlo in 1997. The system is intended to replace traditional automatic gearboxes with smaller devices providing an infinite number of ratios. Unlike all current transmissions, Torotrak's model does not require any device for starting from a standstill such as a clutch or a torque converter. Apart from smoother driving, the infinitely variable transmission (IVT) system is claimed to improve fuel economy by up to 20% and to cut carbon dioxide emissions significantly. This is important for the U.S. market, where many automatic transmission cars are struggling to comply with tough regulations. Torotrak already has licensing agreements with Ford and Toyota. The gearless box has cost BTG £15 million to develop and is expected to require an extra £70 million of investment by Torotrak once it is independent. It is set to go into production by licensees in 2002.

Another innovation aimed at improving the overall energy efficiency of cars has been the development of an electric power-assisted steering (Epas) by Lucas Varity, the U.K. automotive and aerospace engineering group. Previous attempts to develop Epas for cars have often foundered on poor steering "feel" and high costs. Lucas Varity claims that advances in electronics allow its new Epas system to compete with conventional hydraulic power steering on price and performance, and to deliver fuel savings of up to 8%. While power steering is common in North American cars, it is not as widespread in Europe as a consequence of high fuel consumption and other drawbacks of fitting hydraulic steering systems to smaller cars.

The main advantage of Epas is its lower fuel consumption. While a hydraulic system requires a pump to run continuously, draining power from the engine, Epas draws electric power from the battery only when the vehicle is maneuvring, not when it is traveling in a straight line. But previous Epas systems were expensive and could not match the "smoothness" that drivers expect from hydraulic steering. So LucasVarity spent 4 years developing the system to bring the price down to that of a hydraulic system (about £100) and offer similar steering "feel." The key to the Lucas Varity system is a series of patented algorithms (mathematical processes) embedded in the software, which allow precise control over an electric motor, and an optoelectronic sensor mounted behind the steering wheel to measure the force applied by the driver. The system weighs less than 6 kg and bolts directly to the steering column. One vehicle manufacturer has estimated it could be fitted in just 4 minutes on a production line.

The Epas system was fitted experimentally on Rover's MGF roadsters in 1996. In May 1998 LucasVarity agreed a deal with TRW, the U.S. vehicle components group, to develop and manufacture the system. A big European carmaker has signed a development contract that could see Epas used on a small "B" class car in 2000, According to the company, the system will be installed on other smaller cars, where it has clear advantages over hydraulic power steering, before being extended to larger vehicles.

Volvo is to introduce a pollution-reducing catalytic coating to the radiators of its new S80 saloon car range, starting with cars being sold in California early in 1999. The coating, developed by Engelhard, converts ozone molecules into oxygen as air passes through the radiator when the vehicle is in motion. The "PremAir" system was first unveiled just over 3 years ago and initially caused great interest when Engelhard predicted that it would have a market equal to or exceeding that of present autocatalysts in the United States. At the time; however, it was based wholly on platinum and other precious metals technology.

Then Ford, which had been working closely with Engelhard, indicated that although the technology worked well, it might not be as effective in fighting pollution as originally hoped and also appeared to be too costly for volume-produced cars. After a 9 month test period, Ford

Copyright © 1999 Marcel Dekker, Inc.

said it would not use the technology but would monitor Engelhard's progress. The system Volvo will use has been adapted to use cheaper materials, reducing the cost to less than $100 per car (vs. > $1000/car indicated at the time of Ford's involvement).

Volvo, which said it will become the first carmaker to commercialize the technology, claims that the efficiency of the conversion increases with speed, radiator water temperature, and ambient temperature. In the most favorable conditions it is claimed to be capable of converting 75% of the ozone passing through the radiator into oxygen. California has been chosen as a launchpad by Volvo because of that state's increasingly stringent clean air regulations, imposed in an effort to clean up the severely polluted Greater Los Angeles basin in particular.

The technical and performance shortcomings of battery-powered vehicles have already made the California Air Resources Board postpone regulations requiring 2% of new vehicle sales to be "zero-emissions vehicles" (ZEVs). However it retains a program for requiring minimum volumes of low emissions vehicles (LEVS) and ultralow emissions vehicles (ULEVs). The Engelhard technology should thus help Volvo to meet future environmental standards.

One of the more important developments in diesel engine technology has been the introduction of common rail diesel injection. This was originally developed by Fiat in Italy, which licensed it to Bosch. Other suppliers, using the same concept, are now competing with different designs. It is now available in passenger cars, in the Alfa Romeo 156 and certain Mercedes models, and will become more widely available during 1998 and 1999. PSA, for example announced its own design of common rail diesel injection in January 1998.

In essence, the common rail provides a diesel engine with a readily available supply of fuel at a very stable high pressure, which gives earlier and therefore cleaner combustion. In general, higher pressures mean lower emissions. Reduced noise is also a very useful benefit. Common rail systems are superior to conventional distributor (or 'jerk') pumps, through their ability to separate injector timing, engine speed, and volume of fuel delivered. With earlier technologies, these were inherently interconnected.

Engineers are now able to adjust the ignition timing for maximum economy or minimum emissions. The fuel injection profile may also be modified. For example, a small pilot injection is often made in advance of the main injection. Whether these systems will impact fuel quality remains to be seen. All the recent designs run at significantly higher system temperatures, with regular readings as high as 1508C during development work. There may be a need for new fuel stabilizers, antioxidants or detergents. This could be an area of rapid change, since diesel fuel quality is subject to other changes, mainly because of reductions in sulfur.

B. Regulations

1. Safety

Cars are becoming more complex and sophisticated as a result of stricter safety and environmental laws and increasing demands from customers. The trend has been captured by the motor industry catch phrase "more car per car."

The trend toward an increasing use of air bags and side-impact protection bars typifies the emphasis on greater safety. Both concepts were pioneered in Europe, with Mercedes-Benz inventing the original steering wheel air bag and Volvo inventing the side-impact protection system. However, the routine use of air bags was evident first in the United States. These trends are now becoming apparent in Asian markets, particularly on Japanese, South Korean, and Malaysian cars destined for export to the United States and Europe.

Mercedes-Benz announced the development of window bags early in 1998. About 2 m long, the two curtainlike window bags are attached to the inside of the roof frame, between the

Copyright © 1999 Marcel Dekker, Inc.

front and rear roof pillars. They inflate within 25 ms of impact, creating a protective cushion for the head and upper torso of front and rear seat occupants on both sides of the car. The bags, which are about a foot deep and 2 inches thick, work in conjunction with side and front bags, making a total of eight bags, which can inflate simultaneously in a collision, and also act as a shield against any broken glass that enters the passenger compartment.

Mercedes-Benz is to launch the window bags initially as optional equipment on its E-class models, starting in July 1998. The system will cost about £300. Side air bags, mounted in the vehicle doors, will also be offered as an option as part of an overall safety package from July and will include seat belt tensioners. Mercedes-Benz estimates the overall cost will be slightly more than £600.

Bosch, the world's biggest independent car parts group, is planning to increase 1998 sales of its innovative Electronic Stability Programme (ESP) for avoiding car crashes by a factor of 10, from under 50,000 units in 1997 to around 500,000 units. ESP rose to prominence in October 1997 after Mercedes-Benz decided to fit the antiskid system as standard equipment to improve the stability of its new A-class small car. Bosch believes that sales of ESP equipment will be in the range of millions of units a year within a few years.

The increased interest, which stems from the much publicized tendency of the unmodified A class to overturn in certain extreme maneuvers, has led volume carmakers to offer ESP technology much sooner than expected. According to Bosch's original plans, installation would be restricted largely to luxury models, with demand only gradually trickling down to the volume sector, as happened with antilock brakes 10 years ago.

The decision by Mercedes-Benz means that the market is expanding faster than initially forecast. Bosch, which installed the first ESP system in 1995, is now working on new generations that will be simpler and cheaper to manufacture. The company believes that it will be able to retain its lead, despite movement by other manufacturers of electronic braking technology into ESP. Bosch also plans to expand in the market for brakes in the heavy commercial vehicles sector. Talks are in progress to join the international joint venture between Knorr-Bremse, the privately owned German brake specialist, and Allied Signal of the United States. While Knorr and Allied Signal had a strong presence in hydraulic braking systems for trucks, Bosch has specialized in electronic technology.

Suppliers of electronic equipment are enjoying a boom in sales as a result of the development of "intelligent cars." The value of such components reached $49 billion in 1997 and is forecast to soar by 53%, to $75 billion, by 2002. The increase will be spread almost uniformly across the major vehicle-producing regions of the world. Within the total, the value of satellite-based car navigation systems will jump more than sevenfold, to $7.5 billion from $1 billion in 1997.

Radar equipment is forecast to start penetrating the market for the first time, together with the electronics needed to integrate it into the automatic collision avoidance systems that will be a major feature of the cars of the future. Mitsubishi already has one such system in production, for its Diamante model. Most other major carmakers are following suit, creating a valuable new market for companies already producing aerospace radar (e.g., Delco Electronics, TRW, and Rockwell in the United States, Dasa and Thomson in Europe, Mitsubishi Electric in Japan, and Hyundai in South Korea).

Even more sophisticated safety systems will be capable not only of keeping a car a safe distance from vehicles in front but of following the curves of roads without driver intervention. Mercedes-Benz and Honda are already testing such systems. All these systems are dependent on the increasingly intensive use of on-board electronics, helping increase the total value of a vehicle's content accounted for by electronics. It will be further increased as a result of the

Copyright © 1999 Marcel Dekker, Inc.

introduction of "smart" air bags, capable of detecting whether a seat is actually occupied before deploying in a collision, Epas, active stability control (preventing the driver losing control in a corner), and electronic "neural networks" to control functions and systems throughout the car.

2. Environmental

The EU took a particularly proactive stance on reducing greenhouse gas emissions at the Kyoto conference at the end of 1997, and this has been continued over CO_2 emissions from motor vehicles. The motor industry in Europe, has made a number of well-publicized agreements with national governments to improve fleet average fuel economy and thereby to reduce CO_2 emissions. However, the European Commission has been pressing for further reductions.

European vehicle companies have been coming under intense pressure to agree to a voluntary cut in CO_2 emissions from cars and trucks, after indications that failure would lead to the imposition of binding targets. EU countries believe car companies should play a leading role in helping meet targets for cutting carbon dioxide emissions agreed at the 1997 conference on global warning in Kyoto.

In mid-1997, the companies, represented by ACEA, offered to cut emissions to an average of 155 g of carbon dioxide per kilometer in new cars by the year 2005. This compares with a 1995 average of 171 g/km. EU nations said they wanted a target of 120 g and asked the commission to report back on the industry's response by a meeting of environment ministers by March 1998. Carmakers said a target at that level would force some companies out of business. They are already facing a bill of billions of dollars to cut emissions of pollutants under the EU's Auto-Oil Programme to cut exhaust pollutants. ACEA argued that European carmakers had to avoid being placed at a competitive disadvantage to competitors from outside Europe.

In December 1997 the EU Environment Council considered progress to be inadequate toward a Europe-wide voluntary agreement and urged the commission to propose an EU directive with binding reduction targets. A fleet average of 120 g/km CO_2 by 2008 was recommended. The motor industry responded in March 1998 with a proposal for 140 g/km, but with three conditions:

no unreasonable restrictions on diesel vehicles
full availability of low sulfur fuel by 2005
full availability of fuels with appropriate fuel economy features, such as cetane number

This offer was welcomed in May 1998 by the environment ministers of the 15 EU nations, although they called for talks aimed at achieving a further cut. They see bigger cuts as an essential element in achieving the commitment by the EU at the Kyoto conference to cut greenhouse gases by 8% from 1990 levels by 2012. The European Commission is working toward a target of 120 g/km for CO_2 emissions from average cars, although it acknowledges that measures will be needed in addition to any deal with carmakers.

By mid-1998, after much discussion in 1997, new regulations on passenger car emissions and fuel quality for 2000 have been almost agreed, although a significant gap still exists between the Council of Ministers's proposal of 350 ppm maximum for diesel fuel sulfur and the European Parliament's demand for a maximum of 200 ppm. The aromatic content of gasoline continues to be a contentious subject, but the conciliation process to resolve the differences is progressing. The year 2000 proposals are listed in Table 12.

In February 1998 the European Parliament adopted some amendments to the council's common position, including mandatory fuel limits for 2005. These appear in Table 13, with the changed vales from the 2000 proposals shown in boldface type. The process is likely to go to "conciliation" (direct negotiation between the council and me Parliament), with the final outcome delayed until later in 1998.

Copyright © 1999 Marcel Dekker, Inc.

Table 12 European Fuel Specification: Year 2000 Proposals[a]

Gasoline 2000	CM, October 1997	EP, February 1998	Diesel 2000	CM, October 1997	EP, February 1998
RVP summer, kPa max	60	60	Sulfur, mg/kg max	350	200
RVP arctic grade, kPa max	70	70	Distillation (95% pt) °C max	360	360
Sulfur, mg/kg max	150	150	Polyaromatics, % m/m max	11	11
Benzene, % v/v max	1.0	1.0	Cetane number (min)	51	51
Aromatics, % v/v max	42	35	Density at 15°C	0.845	0.845
Olefins, % v/v max	18	14			
Oxygen, % m/m max	2.3	2.7			
RON (min)	95	95			
MON (min)	85	85			
Evaporation at 100°C, % v/v max	46	46			
Evaporation at 150°C, % v/v max	75	75			
Trace lead, g/L max	0.005	0.005			

[a]CM, Council of Ministers; EP, European Parliament; RVP, Reid vapor pressure; RON, Research octane number; MON, Motor octane number.
Source: European Commission.

Table 13 European Fuel Specification: Year 2005 Proposals[a]

Gasoline 2005	CM, October 1997	EP, February 1998	Diesel 2005	CM, October 1997	EP, February 1998
RVP summer, kPa max	60	60	Sulfur, mg/kg max	50	50
RVP arctic grade, kPa max	70	70	Distillation, (95% pt) °C max	360	340
Sulfur, mg/kg max	50	30	Polyaromatics, % m/m max	11	1
Benzene, % v/v max	1.0	1.0	Cetane number (min)	51	58
Aromatics, % v/v max	35	30	Density at 15°C	0.845	0.825
Olefins, % v/v max	18	14			
Oxygen, % m/m max	2.3	2.7			
RON (min)	95	95			
MON (min)	85	85			
Evaporation at 100°C, % v/v max	46	46			
Evaporation at 150°C, % v/v max	75	75			
Trace lead, g/L max	0.005	0.005			

[a]CM, Council of Ministers (indicative levels); EP, European Parliament (mandatory levels); RVP, Reid vapor pressure; RON, Research octane number; MON, Motor octane number.
Source: European Commission.

Copyright © 1999 Marcel Dekker, Inc.

Generally, the new limits for gasoline-engined cars are not arduous, but for diesel vehicles the challenge appears to be much more ambitious. The lobbying was particularly intense during 1997 and 1998, with the arguments contested strongly. Even before Auto-Oil I took effect, the industry started preliminary work on Auto-Oil II, to research the basis for legislative decisions due to come into effect in 2005. Strong differences of opinion about the objectives, function, and time scale of Auto-Oil II exist. Legislative proposals must be complete by June 1999, so data must be collected before the end of 1998.

Some people, including members of the European Parliament, believe that sufficient technical information exists to permit rational decisions about emissions targets and fuel quality for 2005. Of those who support the concept, most of the industry and members of the commission want emissions targets to focus primarily on 2005 legislative issues. Others, including nongovernmental organizations and representatives of Sweden, Finland, and Austria, regard it as an opportunity to address longer range issues (e.g., emissions that are not currently regulated) and would like to see the time scale extended. The situation is likely to be clear only at the end of the conciliation process in 1998. A likely outcome is an administrative compromise. To suit the European Parliament, 2005 emissions and fuel quality limits may be mandated now, but for the council's convenience a compulsory review may be arranged for some time after 2000. The current and proposed emissions limits for vehicles in the EU are listed in Table 14.

Proposals are available for new emissions limits in Europe for heavy-duty engines, to apply in 2000. These proposals are coupled with two new test procedures intended to reflect real-world conditions more accurately. A new steady state cycle with a dynamic smoke test (ESC/ ELR) will be used for all conventional heavy-duty diesel engines, while those with advanced after treatment (De-NO^x catalysts and/or particulate traps) will also have to pass a new European transient cycle test (ETC).

Current three-way catalyst systems for exhaust aftertreatment of gasoline engines work well at normal operating temperatures. Work is now in progress to improve their efficiency during cold starting. Lean-burn direct injection gasoline engines require new De-NO_x technology, for which very low sulfur fuel may be required.

Future aftertreatment systems for diesel engines are less certain. As a result of improvements in fuel injection, it appears unlikely that De-NO_x catalysts or particulate traps will be needed to meet the predicted emissions legislation for 2000, for either passenger car or heavy-duty diesel engines. However, OEMs may have to use such systems to meet the predicted 2005 emissions limits.

Because diesel engines always run lean, the successful De-NO_x "storage and release" approach used by Toyota for gasoline engines may not work as well for diesel engines. New systems are being developed for use in diesel engines, but their introduction is likely be several years behind those for gasoline engines. Selective catalyst reduction (SCR) systems, which use ammonia derived from urea, have been used successfully for stationary diesel engines and have been field-tested extensively by several truck manufacturers, including Daimler-Benz, MAN, and Iveco. Although these systems have been strongly supported by government agencies in Europe, notably the UBA in Germany, urea storage and aftertreatment require a lot of space, making the concept unsuitable for passenger cars. The amount of urea required would double if it were to be used for the whole European commercial vehicle fleet, raising questions about manufacture, storage, and distribution logistics, particularly during cold weather.

Particulate traps appear to be the least favored option by OEMs, owing to their inherent unreliability. However, there may be no other alternative for diesel engine emissions reduction in 2005. Regeneration by burning could be used for commercial vehicles, but additive catalysis is likely to be the best of several options for passenger cars.

Current health and safety evidence suggests that the highest priority will be to limit the

Copyright © 1999 Marcel Dekker, Inc.

Table 14 Current Transposed and Proposed EU Vehicle Emissions Limits

		Emission limits				
		Year 2000 cycle (g/km)[a]			ESC/ELR (g/kW·h)[b]	ETC
Engine type	Pollutant	Cars and LCVs, class I	LCVs, class II	LCVs, class III	Heavy-duty vehicles	
Gasoline 1996/96	CO	3.20	5.96	7.45		
	HC	0.34	0.41	0.48		
	NO_x	0.25	0.30	0.35		
Diesel 1996/97	CO	1.06	1.33	1.59	2.99	7.91
	HC[c]	—	—	—	0.94	1.19
	HC + NO_x	0.71	1.02	1.22	—	—
	NO_x	0.64	0.91	1.09	7.20	7.20
	PM	0/08	0.12	0.17	0.14/0.23[d]	0.23/0.38[d]
Gasoline 2000	CO	2.30	4.70	5.22		
	HC	0.20	0.25	0.29		
	NO_x	0.15	0.18	0.21		
Diesel 2000	CO	0.64	0.80	0.95	2.10	5.45
	HC	—	—	—	0.66	0.85
	HC + NO_x	0.56	0.72	0.82	—	—
	NO_x	0.50	0.65	0.78	5.0	5.0
	PM	0.05	0.08	0.11	0.10/0.13[d]	0.16/0.22[d]
Gasoline 2005	CO	1.00	1.81	2.27		
	HC	0.10	0.13	0.15		
	NO_x	0.08	0.10	0.11		
Diesel 2005	CO	0.50	0.63	0.74		
	HC	—	—	—		
	HC + NO_x	0.30	0.39	0.46		
	NO_x	0.25	0.33	0.39		
	PM	0.025	0.04	0.06		

[a] All limits expressed on the year 2000 test cycle, with 40-second warm-up period omitted.
[b] All limits expressed on ESC/ELR and ETC cycles applicable from year 2000 (EURO III). ESC, European steady state cycle; ELR, European load response test; ETC, European transient test cycle.
[c] Hydrocarbons are not subject to regulation, only HC + NO_x are regulated. For heavy-duty engines, HC is treated individually.
[d] The first total particulate matter (TPM) limit applies to all diesel engines. The second TPM limit applies to diesel engines with a swept volume of less than 0.7 L per cylinder and a rated power speed of more than 3000 rpm.
Source: European Commission.

number of very fine particles emitted by diesel engines, rather than the total number of particles. This could shift the arguments about De-NO_x catalysts and particulate traps in favor of the latter. It may also raise new questions about the relative safety of gasoline and diesel engines, and it may even raise new questions about fuel quality.

Critics of the European Commission's strategy claim that improving fuel efficiency does not necessarily lead to reduced emissions. They point to the United States, where the corporate average fuel economy (CAFE) scheme played a central role in doubling the fuel efficiency of new cars between 1978 and 1985. Yet it failed to achieve its ultimate goal of cutting oil imports because people were driving more. Between 1973 and 1992, the number of cars on American

Copyright © 1999 Marcel Dekker, Inc.

roads rose from 126 million to 200 million. The average distance driven in each car also increased.

CAFE, say the critics, has done nothing to influence overall consumer choice toward more fuel-efficient vehicles, and the European Commission may be in danger of making the same mistake. Making cars more efficient is one thing. Getting people to buy them is quite another matter.

Currently, the most stringent regulations for emissions from motorcycle engines are in Austria and Switzerland, as shown in Table 15. Overall EU regulations are less stringent than in the United States, so it is possible that Europe will focus increasing attention on reducing emissions from both two- and four-stroke motorcycle engines.

It might be difficult to see why two-stroke engines should be encouraged from the perspective of emissions alone. Conventional two-stroke engines must pass the fuel–air mixture through the crankcase then into and (as exhaust) out of the cylinder through fixed ports opened and closed by piston movement. Even at their most efficient, combustion temperature is high and so, consequently, are NO_x emissions. Wet sump lubrication is not possible, so oil must be carried in the fuel–air mixture, burning with it and contributing to HC emissions. Because of the fixed porting, the engine is at its most efficient only rarely; at other speeds and loads a proportion of the mixture passes straight through the combustion chamber unburned, making for high fuel consumption and further increases in HC emissions. A measure of the challenge to a lean-burn compact two-stroke is that current EU legislation tolerates around 10 times the emissions from a small two-stroke scooter than it does from a car.

The answer may eventually be to develop electric or natural gas powered motorcycles. Both Piaggio and Peugeot have announced initiatives to produce battery versions of scooters. Natural gas motorcycles have also been developed by Suzuki and NGV Corporation (Canada).

Table 15 Statutory Limits for Emissions of Gaseous Pollutants from Motorcycles

Country	Motorcycle type	Test cycle	Year	Limit (g/km)[a] CO	HC	NO_x
United States	All types, all weights	FTP 75	1983	12.0	4.75	—
European Union	2-stroke, <100 kg	EU	Not yet enforced	12.8	8.0	—
	2-stroke, 100–300 kg			12.8 + 19.2 × [(*M* − 100)/200]	8.0 + 12.0 × [(*M* − 100)/200]	—
	2-stroke, >300 kg			32.0	12.0	—
	4-stroke, <100 kg			17.5	4.2	—
	4-stroke, 100–300 kg			17.5 + 17.5 × [(*M* − 100)/200]	4.2 + 1.8 × [(*M* − 100)/200]	—
	4-stroke, >300 kg			35.0	6.0	—
Austria	2-stroke	EU	1990	8.0	7.5	0.1
	4-stroke	EU	1990	13.0	3.0	0.3
Switzerland	2-stroke	EU	1990	8.0	3.0	0.1
	4-stroke	EU	1987	13.0	3.0	0.3
Japan	No regulations					
Taiwan	All types, all weights	EU	1993	2.11	0.875	

[a] *M* = mass (weight) of motorcycle in kilograms.
Sources: SAE, IFP, JASO, Pathmaster Marketing.

Copyright © 1999 Marcel Dekker, Inc.

V. DEVELOPMENT OF MARKETS FOR SYNTHETIC AUTOMOTIVE FLUIDS IN EUROPE

Europe is already the world's largest market for synthetic and part-synthetic automotive lubricants. Overall, around 5% of gasoline engine oils are fully synthetic, between 15 and 18% of gasoline engine oils are part synthetic, and almost 10% of heavy-duty diesel engine oils are part synthetic in Europe. These figures, however, mask some wide differences among European countries. Sales of synthetic and part-synthetic engine oils are highest in Germany, France, the United Kingdom, Sweden, Austria, and Finland and very much lower in Spain and Portugal. Italy, Belgium, and the Netherlands are intermediate.

Sales of part-synthetic engine oils are rising steadily across Europe, but particularly in the German-speaking countries as well as France, the United Kingdom, Sweden, Finland, and Italy. Sales of fully synthetic lubricants (excepting Mobil 1 and Castroi RS/Syntron) are believed to be flattening, as some fully synthetic products are withdrawn by companies on the grounds of consumer resistance to the high costs. The increased sales of part-synthetic oils are now leading to significant increases in demand for both poly(α-oleflns) and esters from lubricants blenders. With the introduction of 0W-30 grades in many countries, these volumes will continue to rise.

Overall the message from the market is that the technical understanding of synthetics' unique properties has been increasing for some years. Some applications have been lost to one synthetic, but gained by another. Where demonstrable advantages can be assessed (e.g., in high performance gasoline engine oils), there is a solid acceptance at all levels, from OEMs, lubricant companies, and customers; this is the key to success. If any of the three elements of consensus is missing, there is only disappointment and frustration.

The use of synthetic and part-synthetic automotive lubricants in Europe received a major boost in the 1980s from the introduction of the NOACK test and is now receiving a second as a result of biodegradability, or toxicity problems, generally summarized as environmental issues.

Overall, synthetics and part synthetics still have less than 2% of the lubricants market, worldwide, although their combined share of the automotive lubricants market in western Europe was over 20% in 1997. What is a realistic worldwide target? Probably 5% within a decade would be a major achievement, with an ultimate upper limit of 10%: that is, about 3 million metric tons. Fundamentally, meeting this goal would necessitate major changes in engine oil makeup or performance requirements. Success would come more quickly if the U.S. market were to move to higher quality specifications, especially on volatility.

The market for automotive engine oils has been through a period of unprecedented change in terms of industry specifications, product development, and customer expectations at a time of low overall growth in demand for products. This has caused problems of profitability for additive manufacturers and base oil producers, in addition to opportunities for companies with marketing and service support skills.

The primary observation is that suppliers with higher performance products, better marketing, and attention to service support are more likely to take market share from suppliers that lack one or more of these customer-driven attributes.

Copyright © 1999 Marcel Dekker, Inc.